HIGH-TENSION TRANSMISSION MEETING AT CHICAGO, JUNE 21-22, 1904.

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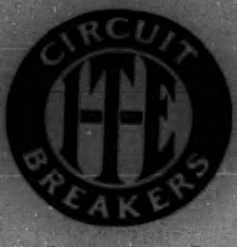

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

ASSOCIATES ELECTED FEBRUARY 26, 1904.

Name.	Residence.	Endorsers.
ATKINS, ULYSSES SAGE,	Chief Engineer, Lewiston Water and Power Co., Asotin, Washington.	F. J Englehorn. D. L. Huntington. A. E. Ransom.
ALEXANDERSON, ERNST FREDERICK WERNER,	Tester, General Electric Co.; res., 41 Front St., Schenectady, N. Y.	Ernst Danielson. Ralph W. Pope. Ernst Berg.
ALLEN, ELBERT GROVER,	Electrical Engineer, Seattle Electric Co., Seattle, Wash.	S. E. Lindsay Russell Robb. C. R. Cross.
ALLENSWORTH, HARRY RANDALL,	Superintendent of Fire and Police Telegraph; res., 574 Mt. Vernon Ave., Columbus, Ohio.	F. C. Caldwell. R. W. Pope. L. G. White.
ARMACK, JOHN BERNHARD,	Assistant Superintendent, Kilbourne, Jacobs Mfg. Co.; res., 149 E. First Ave. Columbus Ohio.	M. C. Hunter. L. G. White. E. M. Fitz.
BAILEY, FRED. W. C.,	Consulting Engineer, 1210 Harrison Building; res , 40 W. Fourth Ave., Columbus, Ohio.	L. G. White. F. C. Caldwell. M. C. Hull.
BOUCHER, PIERRE J.,	Secretary and General Manager, Standard Water Purifying Co., 505 Century Building, Cleveland, Ohio.	Cloyd Marshall. E. P. Roberts. I. H Sherwood
BOYD VALENTINE,	Power Plant Salesman, Canadian General Electric Co., Ltd.; res., 181 Bloor St., East Tronoto, Ont.	James Kynoch P. E. Hart. C. H. Wright.
BRUNSKOG, VICTOR,	Draftsman, Jeffrey Mfg. Co.; res., 1370 Nei Ave., Columbus, Ohio.	F. L. Sessions E. J. Berg. L. C. Marburg.
BRYANT, JOHN MYRON,	Instructor, University of Illinois, Urbana, Illinois.	Morgan Brooks. W. H. Williams. H. B Smith.
BUTLER, WILLIAM WILSON SAMUEL,	Engineer and General Manager, Durham Traction Co., Durham, N. C.	Clariborne Pirtle. R. H Pierce E. P Coles.
CAMPBELL, JOHN,	Consulting Engineer, 14 Warren Ave., Chelsea, Mass.	C. B. Burleigh. J. I. Ayer. Ralph W. Pope.

CHASE, BURDETTE LEONARD, Superintendent of Line Construction, Columbus Railway and Light Co.; res., 43½ N. High St., Columbus, Ohio.	L. G. White. Sheldon Roberts. M. C. Hull.
CLARK, THOMAS E., Electrical En ineer, Thomas E. Clark Wireless Telegraph and Telephone Co., 309 Stevens Building, Detroit, Mich.	T. C. Martin. H. G. Field. J. H. Livsey.
CONANT, STUART MORTIMER, Southern Representative, Crocker-Wheeler Co., 425 Empire Building, Atlanta, Ga.	A. M. Schoen. A. K. Selden, Jr. W. B. Spellmire.
COOK, HARRY LAWRENCE, Inspector of Lighting Department, Columbus Railway and Light Co.; res., 1258 Michigan Ave., Columbus, Ohio.	F. C. Caldwell. L. G. White. Ralph W. Pope.
COOKE, JOHN WILLIAM, Operating Department Engineer, Electric Storage Battery Co., 60 State St., Boston, Mass.	Hugh Lesley. W. L. Puffer. P. W. Davis.
DARRACH, BRADFORD, JR., Construction Engineer, Electric Storage Battery Co., 60 State St.; res., 39 Stanhope St., Boston, Mass.	Edward Campbell. C. W. Hogan. Ralph W. Pope.
DAVIS, CHARLES STAPLES, Master Electrician, Navy Yard, Boston; res., 94 Pearl St., Somerville, Mass.	C. W. Holtzer. D. M. Bliss. C. B. Burleigh.
DECKER, RUDOLPH J., Mechanical and Electrical Engineer, Salt Lake City, Utah.	A. F. Ganz. D. S. Jacobus. Ralph W. Pope.
DEMAREST F. A., General Superintendent Interstate Telephone Co., 18 So. Stockton St., Trenton, N. J.	W. W. Olheiser W. L. Hodges. B. C Groh.
ENTZ, THEODORE B., Branch office manager, Electric Storage Battery Co., 1204 Continental Trust Building, Baltimore, Md.	Philander Betts. Charles Blizard. J. B Entz.
ETTRUP, LAWRENCE, Consulting Engineer, Sacramento Ashburton Mining Co., Room 36, Physician Building, Sacramento, Cal.	R. H. Black. C. W. Hutton Robinson Crowell
GAIENNIE, FRANK, JR., Superintendent Switchboard, Kinloch Telephone Co.; res., 3935 Sullivan Ave., St. Louis, Mo.	William Reid. H. L. Reber. Ernst Ruebel
GOUGH, EDGAR W., Electrician, Stanley Instrument Co., Great Barrington, Mass.	William Stanley. W. C. Andrews. J. F. Kelly.
GUDEMAN, LEO, Designer, Jeffrey Mfg. Co ; res., 870 Neil Ave., Columbus, Ohio.	F. L. Sessions. R. R. Dunlap. Max Osterberg.
HAUGHTON, ERNEST HARLAN, District Manager, Bryan Marsh Co., 50 Perin Building, Cincinnati, Ohio.	Emil Schmid. F. C. Colwell. R. B. Owens.
HOPKINS, WILLIAM A., JR., President, Erner-Hopkins Co.; res., 370 N. High St., Columbus, Ohio.	F. C. Caldwell. L. G. White. M. C. Hull.
KRANTZ, HUBERT F., President and Treasurer, H. Krantz Mfg. Co., 160 7th St.; res., 610 11th St., Brooklyn, N. Y.	W. H. Heath. C. O. Mailloux. C. E. Knox.
LEITCH, JOHN INGRAM, Manager Albernee Stone Co., 54 N. Clinton St., Chicago; res., 307 Davis St., Evanston, Ill.	W. A. Blanck. P. Junkersfeld. Carl Schwartz.

LIND, EMILE G., Representative, Accumulatoren-Fabrik Aktiengessllleschraft, 17 Queen St., Melbourne, Aus.	J. T. Wolfe. F. A. McCarty. J. M. Jolly.
LEVY, MAX J., Salesman, The Burnet Co., 121 Maiden Lane; res., 242 W. 121st St., New York City.	Max Osterberg. H. D. Patterson. H. B. Coho.
LIBBY, ALBION DANA TOPLIFF, Assistant Engineer, Kellogg Switchboard and Supply Co., 130 So. Willow Ave., Austin, Ill.	K. B. Miller. F. W. Dunbar. F. J. Dommerque
LIGGETT, WILLIAM KELSEY, Engineer, Kinkade & Liggett Co., 238 N. 18th St., Columbus, Ohio.	F. C. Caldwell. M. S. Browne. M. C. Hull.
MAUTNER, CHARLES, Manager, H. Krantz Mfg. Co., 160 7th St., Brooklyn; res., 1476 Lexington Ave., New York City.	W. H. Heath. C. O. Mailloux. C. E. Knox.
MCCASKILL, KENNETH, Testing Department, General Electric Co.; res., 207 Victory Ave., Schenectady, N. Y.	R. B. Owens. C. P. Steinmetz. W. I. Slichter.
MCCLELLAN, WILLIAM, Engineer, Philadelphia Rapid Transit Co.; res., 1313 Divinity Pl., Philadelphia, Pa.	W. S. Aidrich. M. E. Leeds. H. H. Norris.
MCFEELEY, JOHN, Assistant, Public Service Corporation of New Jersey, 418 Federal St.; res., 615 Line St., Camden, N. J.	Paul Lupke. J. E. Cutler. W. W. Olheiser.
MONASMITH, EDWARD H., Contracting Agent, Columbus Railway and Light Co.; res., 2480 Findlay Ave., Columbus, Ohio.	L. G. White. M. C. Hull. Ralph W. Pope.
MOORE, JOHN H., In charge Electrical Equipment of Station 4, Columbus Edison Co.; res., 311 Arondale Ave., Columbus, Ohio.	Perry Okey. L. G. White. Sheldon Roberts.
PARKIN, FREDERICK JAMES, Construction Foreman, Canadian General Electric Co.; res., 226 Bleecker St., Toronto, Ont.	R. T. MacKeen. J. A. Kammerer. James Kynoch.
PEIRCE, ALBERT EDWIN, JR., Assistant Electrical Engineer, Pennsylvania Steel Co.; res., 52 Second St., Steelton, Pa.	E. D. Edmonston. H. L. Wallau. Hugh Pattison.
PIXLEY, MILTON ADOLPHUS, Superintendent of Construction, Erner Hopkins Co.; res., 477 Linwood Ave., Columbus, Ohio.	M. C. Hunter. L. G. White. F. C. Caldwell.
PRYCE, EDMUND HUGH, Constructing Electrical Engineer, N. E. National Automatic Fire Alarm Co.; res., 135 Sylvan St., Rutherford, N. J.	Leo Daft. F. E. Idell Ralph W. Pope
READ JOHN ROYALL, Electrical Engineer, Northern California Power Co., Whitmore, Cal.	C. E. Downton C. F. Scott. D. C. Rockwood.
REID, HARRY PALMER, Engineer, Stanley Electric Mfg. Co., Pittsfield, Mass.	Leonard Wilson. Gilbert Wright. D. B. Rushmore.
RICH, SIDNEY LEONARD, Purchasing Agent, B-R. Electric Co.: res., 330 S. Pryor St., Atlanta, Ga.	A. M. Schoen. H. J. Ryan. H. H. Norris.
SACKETT, L. A., President, Sackett Mine Supply Co., 77 E. Long St., Columbus, Ohio.	M. C. Hull. F. C. Caldwell. L. G. White.

SARGENT, FRANK C., Chief Electrician, Malden Electric Co., Malden, Mass.	C. B. Burleigh. E. E. Boyer. J. I. Ayer.
SCOTT, SAMUEL, Storage Battery Expert, Jeffrey Mfg. Co.; res., 332 Donaldson St., Columbus, Ohio.	R. R. Dunlap. F. L. Sessions. L. G. White.
SEEDE, JOHN AUGUSTINE, Designing Engineer, General Electric Co.; res., 133 Lafayette St., Schenectady, N. Y.	J. E. Noeggerath. A. E. Averett. K. A. Pauly.
SMITH, SAMUEL HOLMES, Engineer, Stanley Electric Mfg. Co., Pittsfield, Mass.	Leonard Wilson. Gilbert Wright. D. B. Rushmore.
SPEAR, JAMES OTIS, JR., Salesman, Ft. Wayne Electric Works, 1100 Penn Square, Philadelphia, Pa.	E. M. Archibald. H. K. McCay. C. P. McCluer.
STABLER, HAROLD BROOKE, Chief Inspector, Chesapeake and Potomac Telephone Co.; res., 1214 I St., Washington, D. C.	F. A. Wolff. W. H. Tapley. Ralph W. Pope.
STEWART, HARFORD TOLAND, Representative, General Electric Co.; res., 846 E. Broad St., Columbus, Ohio.	Mark Simonton. L. G. White. M. C. Hull.
STICKNEY, GEORGE HOXIE, Electrical Engineer, General Electric Co.; res., 51 Tudor St., Lynn, Mass.	W. D'A. Ryan. H. J. Ryan. Ralph W. Pope.
STITES, RICHARD, Secretary Electric Supply and Construction Co., 80 E. Gay St., Columbus, Ohio.	Mark Simonton. L. G. White. M. C. Hull.
TINSLEY, JOHN FRANCIS, Assistant Electrical Engineer, Signal Corps, U. S. Army, San Francisco, Cal.	G. O. Squier. Townsend Wolcott G. A. Hamilton.
TROW, HARRIS CUSHMAN, Instructor, Armour Institute of Technology; res., 4217 Ellis Ave., Chicago, Ill.	J. E. Snow. J. R. Cravath. C. E. Freeman.
TURBAYNE, WILLIAM ARTHUR, Electrical Engineer, Gould Coupler Co., Lancaster, N. Y.	A. S. Hubbard. W. E. Winship. W. W. Donaldson.
UNDERWOOD, CHARLES W., Manager Westinghouse Electric and Mfg. Co., 780 Ellicott Square; res., 43 Norwood Ave., Buffalo, N. Y.	E. Grissinger. H. B. Alverson. deLancey Rankine
VINAL, ALBERT CARLETON, Assistant Manager, American Tel. and Tel. Co., 15 Dey St., New York City.	H. B. Smith. J. O. Phelon. A. P. Davis.
WATTS, GEORGE W., Assistant to General Manager, Canadian General Electric Co., Ltd., 16 East King St., Toronto, Can.	R. T. MacKeen. James Kynoch. H. W. Weller.
WAXBORN, CARL JOHAN EVALD, Erecting Electrical Engineer, Jeffrey Mfg. Co.; res., 1283 Summit St., Columbus, Ohio.	F. L. Sessions. E. J. Berg. C. E. F. Ahlm.
WHARTON, ELMER BERT, Superintendent, Case Mfg. Co.; res., 84 Pugh Ave., Columbus, Ohio.	M. C. Hull. F. C. Caldwell. L. G. White.

WOODWELL, ARTHUR HOWARD, Meter Tester, Washington Water Power Co., Spokane, Wash.	D.L.Huntington. J. B. Fisken. Robert Howes.
ZAVITZ, RICHARD HERMON, Electrical Engineer, Canadian General Electric Co., Montreal, P. Q.	K. B. Thornton. Ralph D. Mershon. Ralph W. Pope.

Total. 67.

Transferred from Associate to the grade of Member.

HARRY ALEXANDER MAVOR, Engineer and Electrician, 3 Windsor Circus, Glasgow, Scotland.

FRED BRAINARD COREY, Engineer, Railway Engineering Dept., G. E Co., Schenectady, N. Y.

ALBERT HORACE ARMSTRONG, Railway Dept., G. E. Co. Schenectady, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, March 25, 1904.

The 185th meeting was held this date at Carnegie Hall, New York.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following 88 Associates were elected:

ALLEN, FRANCIS RAMSEY, Student, Cornell University, res., 1½ Central Ave., Ithaca. N. Y.	H. H. Norris. H. J. Ryan. J. G. Kellogg.
ANDERSON, WILLIAM, Engineer, Cascade Water Power and Light Co., Cascade, British Columbia.	A. A. Miller. M. P. Randolph. N. J. Neall.
APPLETON, WILLIAM COURTNEY, Sales Agent, General Electric Co., Atlanta, Ga.	A. M. Schoen. E. H. Anderson. A. L. Rohrer.
ASBURY, ORLA FINGEN, Electrical Engineer, D. A. Tomkins Co., 209 S. Myers St., Charlotte, N. C.	F. D. Sampson. Claiborne Pirtle. T. V. Bolan.
BABCOCK, ALLEN HARWOOD, Electrical Engineer, Southern Pacific Co.; res., 1216 Webster St., Oakland, Cal.	F. V. T. Lee. F. A. C. Perrine. J. A. Lighthipe.
BATES, LOUIS W., Assistant with Charles H. Davis, 25 Broad St., New York City; res., 80 Columbia Heights, Brooklyn, N. Y.	G. F. Sever. Paul MacGahan. H. M. Cogan.
BICKEL, ACKERT, Electrical Engineer, with W. K. Palmer, 34 Bunker Building, Kansas City, Mo.	C. P. Barnett. W. N. Gladson. W. A. Treadway.
BLAKE, ELI JUDSON, Draftsman, Electrical Engineers' Office, N. Y. C. & H. R. R. R.; res., 57 N 7th St., Newark, N. J.	W. J. Hammer. Henry Abbott. J. D. Keiley.
BOLDENWECK, FELIX WILLIAM, Engineering Department, Western Electric Co.; res., 27 Stratford Pl., Chicago, Ill.	M. M. Fowler. Carl Wiler. R. W. Pope.
BOND, ARTHUR B., Constructing Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	P. M. Lincoln. E. M. Tingley. W. K. Dunlap.
BONYUN, MORGAN EVAN, Small Motor Specialist, General Electric Co., Atlanta, Ga.	A. M. Schoen. H. J. Ryan. E. L. Nichols.

BORIE, RENSHAW, Westinghouse Electric and Mfg. Co., Pittsburg; res., 913 South Ave., Wilkinsburg, Pa.	C. Renshaw. F. J. Chisholm. D. C. Rockwood.
BOULIGNY, RALPH HUBBARD, Supply Department, General Electric Co., Atlanta, Ga.	A. M. Schoen. J. T. Nyhan. R. W. Pope.
BRADY, WILLIAM BURKE, Superintendent Rossiter MacGovern and Co., 17 Battery Pl., New York City; res., 304 Montgomery St., Jersey City.	Hugh Pattison. C. T. Hutchinson. J. D. Keiley.
BRUCH, CHARLES PATTERSON, Assistant General Manager, Postal Telegraph Cable Co., 253 Broadway, New York City.	T. C. Martin. T. A. Edison. F. J. Sprague.
CANADA, WILLIAM JOSEPH, Electrical Engineer, C. L. & S. R. Co. and D. S. & U. R. Co., 70 Arcade, Springfield, O.	R. W. Pope. E. B. Raymond. A. L. Rohrer.
CANDEE, WILLARD L., Manager, The Okonite Co., Ltd., 253 Broadway, New York City; res., 293 Garfield Pl., Brooklyn, N. Y.	C. W. Price. J. J. Carty. S. S. Wheeler.
CHAMBERLAIN, RUFUS N., Superintendent, Gould Storage Battery Co., Depew, N. Y.	C. L. Edgar. T. C. Martin. G. F. Sever.
CHILDS, JOSEPH SAMUEL, Electrician, 596 William St., Buffalo, N. Y.	C. A. Cora. H. W. Drake. E. P. Harder.
COLES, HENRY A., Salesman, Westinghouse Electric and Mfg. Co., 623 Empire Building, Atlanta, Ga.	A. M. Schoen. C. F. Scott. P. M. Lincoln.
COWLE, GERALD ARTHUR, Commercial Engineer, General Electric Co., Melbourne, Victoria, Aus.	C. A. Bessey. Hewlett Scudder Jr W. I. Slichter.
DAVIS, GEORGE SANFORD, Superintendent, Shawinigan Water and Power Co.; res., 74 St. Denis St., Montreal, Que.	B. C. Shipman. J. A. Walls. R. W. Pope.
DE CASTRO, AMERICO VIEIRA, Chief Engineer, Electric Tramway Co., Porto Portugal.	M. E. J. Touret. M. Coster. R. W. Pope.
DE FODOR, ETIENNE, General Manager, Budapest General Electric Co., VII. Kazinczky utcza 21, Budapest, Hungary.	W. J. Hammer. R. W. Pope. Francis Jehl.
DE FOREST, LEE, Scientific Director and Vice-president, De Forest Wireless Telegraph Co., 100 Broadway; res., 430 W. 118th St., New York City.	T. C. Martin. G. F. Sever. W. D. Weaver.
DIMON, THEODORE, Telephone Engineer, Western Electric Co., 463 West St.; res., 510 West 124th St., New York City.	F. L. Gilman. O.Bell. M.Chester.
DOTY, PAUL, Vice-president and General Manager, Denver Gas and Electric Co., Denver, Colo.	H. B. Dates. R. W. Pope. C. W. Humphrey.
DUNBAR, ROBERT V., Electrical Designer, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City; res., 26 McDonough St., Brooklyn, N. Y.	O. S. Lyford. F. G. Clark. G. L. Hoxie.

EPSTEIN, JOSEPH, Engineer in Chief, Elektrizitäts-Aktiengesellschaft Leerbachstrasse 32, Frankfort am Main, Germany.	Carl Hering. R. W. Pope. William Maver, Jr.
ENGLAND, PAUL WILLARD, Assistant Engineer, Bell Telephone Co., 11th and Arch Sts.; res., 4717 Chester Ave., Philadelphia, Pa.	P. L. Spalding. J. W. Young. C. W. Pike.
EVANS, WILLIAM ALBERT, Assistant Laboratorian, Philadelphia Electric Co., 122 Arch St.; res., 6358 Germantown Ave., Philadelphia, Pa.	J. B. Seaman. A. J. Rowland. L. C. Smith.
FEATHER, ROBERT JOHN, Electrician, Columbus Railway and Light Co., 573½ N. High St., Columbus, Ohio.	L. G. White. Sheldon Roberts. F. A. Fish.
FOREMAN, WALTER EVEREST, Erecting Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	W. K. Dunlap. L. B. Chubbuck. G. W. Fraser.
FRASER, ROBERT M., Draftsman, Westinghouse, Church, Kerr & Co., 10 Bridge St.; res., 566*a* Quincy St., New York City.	A. V. Abbott. R. W. Pope. Horace Dowie.
GABRIEL, GEORGE ANDREW, Superintendent, S. D. Warren & Co., Cumberland Mills, Maine.	N. J. Neall. H. B. Smith. W. S. Murray.
GAINES, CLARENCE AUSTIN, Electrical Inspector, Board of Fire Underwriters of the Pacific, 367 So. 4th East St., Salt Lake City, Utah.	C. L. Cory. G. C. Noble. J. N. Le Conte.
GARNETT, WILLIAM JAMES, Electrician of the Artillery, U. S. Engineer Dept., res., 6 Elliott Pl., Newport, R. I.	A. B. Lisle. P. W. Davis. R. B. Hampson.
GILBERT, CHARLES HENRY, Student, Worcester Polytechnic Institute; res., 11 Dix St., Worcester, Mass.	H. B. Smith. I. O. Phelon. A. P. Davis.
GILES, ARTHUR FULLER, Manager, General Electric Co., Atlanta, Ga.	A. M. Schoen. E. W. Rice, Jr. W. B. Potter.
GOLDMAN, GEORGE TESTER, General Electric Co.; res., 9 Grove Pl., Schenectady, N. Y.	R. W. Pope. R. N. Williams. C. P. Steinmetz.
GOODWILLIE, ROBERT HOGUE, Electrical Engineer, Edison Portland Cement Co., Stewartsville, N. J.; res., 111 Bruce Ave., Yonkers, N. Y.	G. F. Sever. T. A. Edison. F. B. Crocker.
HARVEY, DEAN, Engineer, Electrical Dept., Underwriters Laboratories, 67 E. 21st St.; res., 269 W. Adams St., Chicago, Ill.	G. A. Damon. T. P. Gaylord. C. E. Freeman.
HAZEN, WILLIAM PITT, Chief Engineer, Central Market Street Railway Co., and Columbus, London and Springfield Railway; res., 310 Dakota Ave., Columbus, Ohio.	L. G. White. Darrow Sage. Perry Okey.
HEIDENREICH, HANS EDWARD, Designing Engineer, Russian Electric Co., "Union," Riga, Russia.	C. T. F. Hassler. I. A. H. Glenck. R. W. Pope.
HENDERSON, CLARK TRAVIS, Salesman, Cutler Hammer Mfg. Co., 322 Frick Building, Pittsburg, Pa.	F. S. Wilhoit. A. W. Berresford. H. H. Cutler.

HO, HIDETARO, Assistant Professor, College of Engineering, Imperial University, Tokio, Japan.	W. I. Slichter. Hewlett Scudder. R. W. Pope.
HOLCOMBE, WILLIAM EARLE, General Electric Co., P. O .Box 211, Atlanta, Ga.	A. M. Schoen. R. W. Pope. E. H. Ginn.
HORNE, SANDFORD HENRY, Manager and Engineer, Ind. Electric Construction Co., 31 Second St., San Francisco, Cal.	C. W. Clark. H. A. Russell. J. A. Lighthipe.
HULL, RICHARD EDIE, Manager, The Okani Hull Co., 197 E. Long St., Columbus, Ohio.	Sheldon Roberts. L. G. White. Mark Simonton.
IVES, JAMES EDMUND, Scientific Expert, De Forest Wireless Telegraph Co.; res., 3 West Eighth St., New York City.	W. D. Weaver. H. T. Eddy. A. F. Collins.
JACKSON, PHILIP T., Demonstrator, McGill University, Montreal, Can.	L. A. Herdt. R. B. Owens. R. W. Pope.
JONES, P. N., Manager, Westinghouse Electric and Mfg. Co., 1007 New England Bldg., Cleveland, Ohio.	P. M. Lincoln. C. F. Scott. B. G. Lamme.
KELLER, ARTHUR, Shop Engineer, Northern Electrical Mfg. Co., Madison, Wis.	T. E. Drohan. J. P. Mallet. A. C. King.
LANIER, ALEXANDER CARTWRIGHT, Instructor, University of Tennessee, Knoxville, Tenn.	E. H. Anderson. T. E. Craig. A. K. Selden, Jr.
LAXTON, RALPH ROBERTS, Assistant, General Electric Co., 514 Peachtree St., Atlanta, Ga.	A. M. Schoen. Claiborne Pirtle. F. W. Willcox.
LAXTON, FRED MITCHELL, General Electric Co., Atlanta, Ga.	A. M. Schoen. W. E. Moore. R. W. Pope.
LINDBERG, FRITZ ALBIN, Assistant Electrical Engineer, with George M. Brill, 5832 Indiana Ave., Chicago, Ill.	I. J. Macomber G. M. Brill. J. H. Barr.
LITTLE, JOEL WILLSON, President, Carter & Gillespie Electric Co., 40 Broad St.; res., 82 Oak St., Atlanta, Ga.	A. M. Schoen. J. N. Eley. James Wotton.
LUKES, JOSEPH BRIAN, Superintendent, Seattle Electric Co., Seattle, Wash.	S. C. Lindsay. D. P. Robinson. E. G. Allen.
MABEN, GEORGE SALATHIEL, Engineer and Manager, The City of Wellington, Electric Light and Power Co., Wellington, N. Z.	A. H. Jones. W. L. R. Emmet. M. A. Oudin.
MANLEY, RUSH EMMETT, Chief Inspector, Central Union Telephone Co., 1517 Worthington St., Columbus, Ohio.	L. G. White. B. F. Thomas. F. A. Fish.
MCCULLOH, JAMES S., Superintendent of Buildings, New York Telephone Co., 15 Dey St.; res., 267 W. 71st St., New York City.	J. J. Carty. Bancroft Gherardi H. F. Thurber.
MCGONIGLE, FRANK C., Superintendent, New Castle Electric Co., 154 Wallace Ave., New Castle, Pa.	H. M. Doubleday. J. L. Merrill. A. S. Wattson.

McTaggart, William A., General Electric Co.; res., 427 Smith St., Schenectady, N. Y.	F. B. Corey. H. E. White. J. W. Upp.
Miller, Frank Hegan, Superintendent Louisville Railway Co.; res., 521 W. Hill, Louisville, Ky.	G. W. Hubley. W. J. Davis, Jr. J. J. Mahony.
Morgan, Theodore Blackwell, New York Edison Co., 45 W. 26th St., New York City; res., 61 So. Oxford St., Brooklyn, N. Y.	J. W. Lieb, Jr. W. S. Howell. Calvin W. Rice.
Morrow, Bryce Eugene, Manager Operating Dept., Hudson River Water Power Co., Glens Falls, N. Y.	C. P. Steinmetz. A. L. Rohrer. A. B. Herrick.
Nath, Bangalore Dvaraka, General Electric Co.; res., "The Alexandra," 1 State St., Schenectady, N. Y.	A. L. Rohrer. E. B. Raymond. M. A. Oudin.
Ogle, John Howard, Electrical Engineer, New Orleans Lighting Co., New Orleans, La.	H. J. Ryan. H. H. Norris. Anderson Offut.
Orr, Harry Allen, General Electric Co., Atlanta, Ga.	A. M. Schoen. S. B. Paine. R. W. Pope.
Paige, Nathaniel, Jr., Sales Engineer, Westinghouse Electric and Mfg. Co., St. Louis, Mo.	C. F. Scott. J. R. Bibbins. E. M. Tingley.
Poynton, William Percival, New York Edison Co., 51 West 26th St., New York City.	J. W. Lieb, Jr. Douglass Burnett. Philip Torchio.
Price, William Montelius, Seattle Electric Co.; res., 526 23d Ave., Seattle, Wash.	A. L. Havens. H. W. Huggins. R. Laurie Ellis.
Redding, Samuel Arthur, Assistant Electrical Engineer, Georgia Railway and Electric Co., 133 Cooper St., Atlanta, Ga.	A. M. Schoen. A. Balsley. R. W. Pope.
Reed, Lyman Coleman, Manager, Interstate Electric Co., Ltd., Baronne and Union Sts., New Orleans, La.	W. D. Weaver. C. P. Poole. Edw. Caldwell.
Serrell, Arthur Harold, Patent Solicitor, L. W. Serrell & Son, 302 Broadway, New York City; res., Brooklyn, N. Y.	Jos. Sachs. H. H. Seabrooke. A. P. Jenks.
Sharer, Carl Wadsworth, District Wire Chief, Keystone Telephone Co.; res., 2228 Tioga St., Philadelphia, Pa.	W. L. Hodges. D. F. Stakes. J. W. Kelly, Jr.
Simpson, Frederick Grant, General Manager, Ballard Electric Co., 526 23d Ave., Seattle, Wash.	W. V. Sullivan, Jr. A. L. Havens. K. G. Dunn.
Smith, Arthur Bessey, Assistant Manager, Woodbine Telephone Co., Box 67, Woodbine, Iowa.	Morgan Brooks. E. A. Bessey. C. A. Bessey.
Stone, Frank J., Manager, Electric Storage Battery Co., 60 State St., Boston; res., 66 Highland Ave., Somerville, Mass.	P. W. Davis. L. R. Nash. C. B. Burleigh.
Sugiyama, Seijiro, 31 Nasagocho, Kitakn Osaka, Japan.	C. P. Steinmetz. W. J. Slichter. Hewlett Scudder.

THULLEN, L. H., Electrical Engineer, Union Switch and Signal Co., and Westinghouse Air Brake Co., Pittsburg; res., Edgewood Park, Pa.	C. F. Scott. D. L. Davis. R. W. Pope
TITUS, JOSEPH, VAN EMAN President, Garton-Daniels Co., Keokuk, Ia.	D. C. Jackson. A. E. Kennelly. W. B. Jackson.
WELLMAN, HARLAN PAGE, Superintendent Motive Power, Camden Interstate Railway Co., Lock Box 128, Ashland, Ky.	H. L. Kirker. T. J. Creaghead. G. F. Adams.
WILLARD BEN, Agent, General Electric Co., 1328 2d St., New Orleans, La.	A. M. Schoen. A. M. Lockett. F. W. Willcox.
WITERBY, EDWIN E., Engineer and General Manager, United Gas and Electric Co., 40 Wall St.; res., 1878 7th Ave., New York City.	F. C. Bates. W. W. Cole. E. W. T. Gray.
WILLIAMS, GUY FERANUS, Sales Manager, Bryan Marsh Co., 136 Liberty St.; res., 442 Central Park W., New York City.	W. S. Howell. C. H. Sharp. P. S. Millar.
ZORAWSKI, CONSTANTIN, Designing Engineer, Russian Electric Co., "Union," Riga, Russia.	I. A. H. Glenck. C. F. T. Hassler. R. W. Pope.

Total, 88.

And the following Associate was transferred to the grade of Member.

JOSEPH PHINEAS DAVIS, Chief Engineer, American Telephone and Telegraph Co., 113 W. 38th St., New York City.

The following candidates for officers of the INSTITUTE were selected by the Board of Directors:

President, John W. Lieb, Jr.; Vice-presidents, W. E. Goldsborough, John J. Carty, and Samuel Reber; Managers, Henry G. Stott, Louis A. Ferguson, J. G. White, and S. S. Wheeler; Treasurer, George A. Hamilton; Secretary, Ralph W. Pope.

PRESIDENT ARNOLD:—These new officers, whom we hope to elect at the proper time, will share with the officers who hold over the responsibility of the new duties that are being assumed by the INSTITUTE.

Discussion on "The Relative Fire-Risk of Oil- and Air-Blast Transformers."

F. A. C. Perrine:—As regards the question of the relative fire-risk of oil- and air-blast transformers, the speaker disagrees materially from the conclusions and from some of the premises that Mr. Rice has laid down. The experience of the Fire Underwriters and particularly the practice of Mutual Fire Insurance Companies shows that: "In general that type which contains the greater quantity of inflammable material will occasion the greater fire-hazard" is not generally admitted. On the contrary, the question which is most important is not of the quantity of inflammable material, but of its disposition. Modern mill construction is one which shows a very large quantity of inflammable material, but its disposition is such that the relative exposed surface is small, and this is the most important point. One question relating to the disposition of inflammable material is the presence of dust, not only in connection with the apparatus in question, but throughout the building. In the most important fires—of six or seven—the disastrous consequences have been due to the accumulation of dust. A small fire, where there is dust accumulated, will distribute that fire very widely. In consequence, it seems to me that the fusible link is a very poor protection against fire, because if flame occurs we have the consequent danger from dust. In one instance of a wooden shop a single flame shot out, followed along dust-covered wires, and set fire to all parts of the building, so that the operatives had barely time to escape, although there were doors at both ends and in the centre of the building. This shows the importance in all fire-risks of avoiding the first evidence of flame.

The writer also speaks of the protection that can be obtained by means of systems of piping for draining the oil away from the building and by placing the transformers in a depressed area of concrete arranged for rapid draining. In the speaker's experience there have been three very serious fires in which the transformers have suffered. In one case four 500-kw. transformers were installed on a wooden platform, each transformer containing 14 barrels of oil. The fire occurred by reason of a small arc at the failure of an unimportant low-pressure switch. The fire, by dust and varnish, was immediately conveyed to the woodwork supporting the switchboard and the transformers. When the woodwork burned away the transformers dumped over, the oil spread on the floor, and there was little left of the building or the transformers. A careful investigation was made at the time to ascertain whether the fire had been due at all to the transformers. Every foot of wire in the transformers was gone over by hand to find out whether there was the least evidence of an electric arc. Not only was there no evidence of arcing, but markings on the case were found indicating that so long as the transformers were in

place and the water circulated in the transformer coils, the oil had not even evaporated. There were markings on the cases which showed plainly the level of the oil, and the markings opposite the water-coils showed that the transformers had been sufficiently hot to char the oil opposite the coils inside the transformer, but not to evaporate any considerable quantity of the oil. In the second instance where transformers were involved, the fire was occasioned by reason of a severe short circuit, distributing a flame to the insulation of the wiring in the station and to certain woodwork supports of the switches and other apparatus. The transformers were standing on a smooth cement floor and were not disturbed. All combustible material in the entire plant was destroyed, but on account of the continuous circulation of water in the transformers during the entire fire the only combustibles in the building which did not burn were the oil-transformers, and to-day every coil in every transformer is in operation. The wires were led into the transformers through porcelain bushings, surrounded by wooden bushings simply for the mechanical protection of the porcelain. The wooden bushings were burned out, but the oil was not materially evaporated in the transformers. In one or two of the transformers about one quarter of the oil was evaporated and in these the transformer coils were covered with a black sediment, but on clearing this off the transformers were put into and are still in service, the coils not having been injured.

In another instance a short circuit occurring inside of a 500-kw. transformer, the station attendant maintained the short circuit until he could telephone to the superintendent and have him come to the station. For about 20 minutes black smoke was coming out through the insulation bushings on the case by reason of the actual fire and short circuit which was occurring under the oil in the transformers; there was no flame and no conflagration due to anything inside of the transformers. The oil was simply boiled away.

In a recent instance where a transformer house was destroyed by reason of an extensive wooden framework for wires above the transformers, the latter were also destroyed because the cases were made of thin metal soldered together, and the heat was great enough to unsolder the cases and spread the oil over the floor.

The conclusion to which the speaker arrived from these facts is that the safest transformer, as regards fire-risk, is the one in which the combustible material is so disposed as to present the least surface to fire, and that is the oil-filled transformer. As regards further protection, he believes it is an error to provide means for draining away the oil. On the contrary, for absolute safety the transformer should be installed in a cement pit which can be filled with water, but not above the level of the transformer, because if the water is flowed into the transformer the oil will run out and even oil on the surface of water will catch fire; but

if the transformers are installed in a pit, which can be filled with water from an outside source, the pit can be filled with water and automatically drained away without topping the transformer. The latter is so connected by pipes that no falling part of the building can destroy the water connection of the pipe-coils in the transformer. In this way there is secured the safest possible installation of the transformer. Furthermore in ordinary cases the pit arrangement is entirely unnecessary, if only the water connection be arranged outside of the building so that falling parts of the building cannot destroy the piping. A number of years ago at a meeting of the Pacific Coast Transmission Association, Mr. George P. Low, who is perhaps the best electrical insurance expert on the coast, called attention to the great danger in transformers which have thin cases and particularly those in which the cases are soldered together, because oil can be heated to the temperature which will melt solder without setting the oil on fire. Mr. Low recommended at that time to the insurance authorities that they prohibit the installation, where the building was insured, of a transformer in a case of thin metal, or where a part of a falling building could punch a hole in the metal of the soldered case, or where the soldered metal would melt. This is a wise position which he has taken, and as a consequence that transformer is safest against fire-risk which is an oil-filled transformer, water-cooled, and arranged so that the water can be kept in circulation no matter what happens to the building, and the case of the transformer is strong enough so that falling parts of the building will not puncture it. What the speaker refers to particularly is that when you have a fire which is not complete, and objects weighing 50 or 100 lb. may be falling, the case should be strong enough to withstand such impact and especially should be of such character and strong enough that the fire itself, from the outside, cannot, by melting the case or melting the solder, allow the oil to run out. With these provisions, the oil transformer is by far the safest transformer to install.

J. S. PECK:—The introduction to the discussion on this subject covers the matter in a brief but comprehensive manner, and the speaker is in substantial agreement with all of the statements made therein.

It has been the speaker's experience that the air-blast transformer is more much susceptible to damage by fire which may be caused by static discharges, arcs, bad contacts, etc., than is the oil-insulated transformer, but on account of the relatively small amount of combustible material in the former, and further as it is in solid and not in liquid form, it is possible to have such material entirely destroyed with comparatively little fire-risk to neighboring apparatus or buildings.

In the oil-insulated transformer there is a very much greater amount of combustible material, which, while less likely to take fire, increases the fire-risk to neighboring apparatus or buildings.

Under certain abnormal conditions, it is possible that the oil in a transformer may take fire, consequently it is essential that proper means be adopted for extinguishing the fire and for preventing damage to other apparatus.

There are two sources of danger from the use of oil in a transformer. First, the oil itself may take fire; secondly, a vapor is given off from hot oil, which when mixed with the proper proportion of air gives a highly explosive mixture. This may be ignited by a spark and cause serious damage to the apparatus, and even to the building in which it is contained. The first danger, that of ordinary burning, is fairly well understood: the oil being raised to a high temperature, takes fire, and so long as it can obtain a supply of oxygen, burns with an intense heat and gives off a very dense, black smoke.

The oil used in transformers has a comparatively high burning point (a fire-test of approximately 400° fahr.), and it is necessary that the oil be raised to this temperature before it can be ignited. On account of the large amount of oil in a transformer, it would be necessary to supply a great amount of heat and for some considerable length of time in order to raise the entire body of oil to the burning point,—a condition which rarely or never occurs. It is possible, however, to have local heating in the oil so that a very small portion of it may be raised to a dangerous temperature and this may then be ignited. This local burning, if not stopped, will gradually heat the neighboring portions and result in a general conflagration. Such local heating may be produced, for example, by an arc drawn just below the surface of the oil.

The nature of the second danger; that is, explosions, is not so generally understood. It has been found that with the best proportions of illuminating gas and air under atmospheric pressure the greatest pressure which can be obtained from an explosion is somewhat less than 100 lb. per square inch, and it is probable that with the best mixture of oil-vapor and air at atmospheric pressure, a force of more than 100 lb. per square inch cannot be obtained.

The speaker has made a number of tests on transformer cases with the view of determining the conditions under which combustion of the oil, and explosions of mixtures of oil-vapor and air may be obtained, also to determine the best methods of extinguishing the flames.

A sheet-iron case provided with a tight cover was used; the oil was brought to a burning temperature by means of an electric heater and then ignited by an arc at the surface of the oil. As long as the cover was removed from the case so that a fresh supply of air could be obtained, the oil would burn fiercely, giving off a dense, black smoke. Placing the cover on the case would almost instantly extinguish the flames. It was also found that a liquid chemical fire-extinguisher was very effective but did not act so quickly as the method of excluding the air.

As long as the oil was maintained at a temperature slightly above the fire-point no explosion was obtained, but when the oil was raised 30° to 50° above the fire-point, so that fumes were given off at a very rapid rate, it was possible to obtain an explosion which would lift the light sheet-iron cover several inches off the case. If it settled back over the case the flames would be immediately extinguished. This explosion could be obtained with almost every trial, but not unless the cover was first removed and a supply of air permitted to mix with the oil-vapor. From the nature of these explosions it was evident that the pressure per square inch at the time of the explosion was very small. The test was of a qualitative instead of a quantitative nature, and no attempt was made to find definitely the exact pressure generated.

In this connection, another instance is worth citing. A transformer which had been removed from the oil, and therefore thoroughly oil-soaked, took fire from a torch used for unsoldering a connection. In a few seconds the insulation was burning fiercely; the transformer was quickly replaced in the tank of oil, and the flames were immediately extinguished.

From these tests it is apparent that if a transformer case can be made reasonably air-tight, combustion of the oil cannot continue. Where it is possible to use a riveted boiler-iron case with cast-iron cover, it may be constructed so that it will readily withstand a pressure of 100 lb. per square inch, and if it is properly vented a pressure above atmospheric cannot be obtained before the explosion unless vapor should be given off from the oil at such a rate that its escape is throttled by the vent-pipe, an almost impossible condition with a vent-pipe of suitable size. Even if vapor is given off at such an enormous rate, it seems likely that the supply of air would be driven out from the case, so that the mixture left would have little or no explosive force. Where this type of construction can be used, it seems desirable to make the case of sufficient strength to withstand an internal pressure of 100 lb. per square inch with a reasonable factor of safety, and to provide a vent-pipe of suitable size. In such a case oil cannot burn, and should an explosion occur it can do no harm.

Where a self-cooling sheet-iron case is used, it is impossible to make it sufficiently strong to withstand an internal pressure of 100 lb. per square inch, and for such construction it seems best to make the case practically air-tight so that oil cannot burn in it, and to provide a large safety-valve which will be lifted in case of an explosion and will then automatically close, thus extinguishing the flames.

It is well to consider carefully all dangers, no matter how remote they may be. How remote is the danger from the oil-insulated transformer is shown by the fact that, although there are several thousands of them operating to-day, many of an old type and often installed without apparent thought of the

fire-risk, it is probable that the number of cases of serious trouble resulting from oil fires may be counted upon the fingers of one hand, and in the majority of these cases the trouble has started outside the transformer. In fact, the speaker knows of but one instance where the transformer was directly responsible for the trouble. This was the recent fire at Snoqualmie Falls, Washington, and as it bears directly on the matter under discussion, the following facts will be of interest:

The water-wheels and generators at Snoqualmie are located in a pit about 250 feet below the top of the falls. The raising transformers are located in a building at the top of the pit. There were twelve 550-kw. self-cooling transformers located in the same room.

The first indication of trouble was the melting of the insulation from the conductors leading to the transformers. When an attendant reached the transformer house one transformer was found to be on fire; this was extinguished by means of a Babcock extinguisher. It was then discovered that another transformer was on fire, but as the contents of the extinguisher had been exhausted and as there were no other means of extinguishing the flames, they soon burned through the wooden top covering the case, then melted the solder in the side of the case, thus permitting the burning oil to flow out upon the floor. The burning oil melted the solder in the seams of the other cases and permitted the additional oil to flow out. The conduits for the low-tension leads acted as a drain and carried the burning oil down into the wheel-pit, and for a time the whole plant was threatened with destruction. Fortunately the flames were extinguished without other loss than the transformer house, part of the transformers, and the low-pressure cables. This trouble at Snoqualmie Falls, taken in connection with other information concerning oil transformers, leads to certain conclusions:

1. Where practicable, the transformers should be placed in a boiler-iron case, capable of withstanding an internal pressure of 100 lb. per square inch, the case to be suitably vented.

2. Where a sheet-iron construction is necessary, the case should be made practically air-tight and provided with a very large safety-valve, so that an internal explosion cannot burst the case.

3. Provision should be made for rapidly drawing off the oil in case it becomes necessary to do so.

4. Individual transformer units, or groups of units should be located in fire-proof compartments, such compartments to be suitably drained so that in case the oil escapes from the cases it can flow out where it can do no harm.

5. Adequate means should be provided for extinguishing fire, and the station attendants should be trained to know what to do in case of emergency.

With such reasonable precautions the fire-risk to other apparatus from oil-insulated transformers will be no greater than

from air-blast transformers; with either type the fire-risk is practically negligible.

Dr Perrine has referred to the fire-risk of transformers mounted in cases made of sheet-metal, having seams riveted and soldered, and has pointed out the greater safety of the water-cooled transformer mounted in a boiler-iron case with seams riveted and caulked. Unfortunately this latter construction cannot be used on cases for large transformers of the self-cooling type; and as there is and will continue to be a great demand for self-cooling transformers it will be necessary to take such precautions in the installation as will reduce to a minimum the fire-risk resulting from cases of this type. It is, of course, recognized that a self-cooling case made without rivets and solder is to be greatly desired. It is hoped that a case of such construction may at some time be devised.

CALVERT TOWNLEY:—Strongly emphasized the fact that neither type of transformer constitutes a serious fire-hazard. He stated that such fire hazard as does exist should be divided into two classes; first, a source internal; secondly, a source external to the transformers themselves. The papers and most of the previous discussion has had to do with the internal source of fires, but if transformers themselves constitute a low fire-hazard the internal source is of minor importance. The chief danger from internal fire is perhaps the blast of air in an air-cooled transformer, which may carry internal fire to adjacent apparatus or to inflammable parts of the building. It is sometimes but not always possible or easy to place transformers so that the exhaust air will impinge only on non-combustible materials. An automatic device for shutting off the air, which may not be operated for several years, is not likely to work when it is necessary.

For a fire external to transformers the air-blast type is more subject to attack:

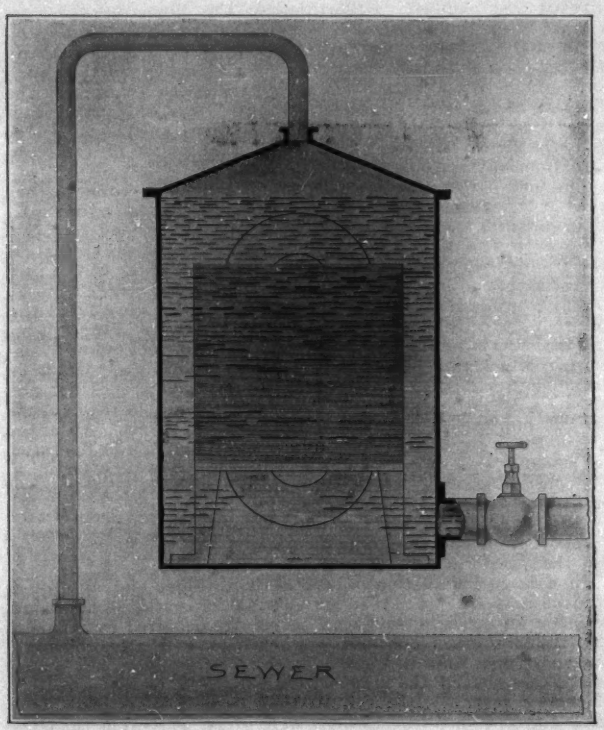
First, from flames, because it has no protecting case.

Secondly, from water, which, while it will not destroy, may put the transformer out of service for many days.

In a large installation, where both air-blast and oil-cooled transformers are installed in about equal capacities in the same transformer house, a somewhat severe fire occurred external to the transformers. The fire was extinguished after burning furiously for a time without damage to either type, but water completely soaked the air-blast transformers, which were out of service several days or until they became thoroughly dry, while the oil-cooled transformers were in use as soon as the connections could be re-established; that is, in a few hours.

Many people are misled as to the risk from oil-insulated transformers by the word "oil." That word suggests kerosene and the idea of very inflammable material, whereas oil of 400° fire test, such as is used for oil transformers, is far from an inflammable material at any but very high temperatures. A burning brand may be plunged into it and the fire will be extinguished.

Both types of transformer can be constructed and installed so that the fire-risk will be very small, and there is no reason why engineers or manufacturers should particularly favor the use of either type against the other.



RALPH D. MERSHON:—The speaker must differ from Mr. Townley in regard to one statement and that is that the fire-risk due to high pressures is greater than with lower pressures; if anything, the contrary is true. The speaker agrees with Dr. Perrine in regard to the relative fire-hazard, that it is not entirely de-

pendent on the amount of inflammable material, but is dependent more on the location and distribution of material. It also depends on the relative effectiveness of the provisions that can be taken for coping with fire. The scheme of installing oil transformers in separate rooms is not the best practice. In the case of high-pressure transformers it involves complications in wiring which are not advisable to use. The speaker is in favor of bare wiring for high pressures, and the moment you put these transformers in separate rooms you get into trouble with the high-pressure wiring. If the rooms are to be a thorough protection against fire they must be in the nature of vaults, which makes the wiring still more difficult. If the transformers are surrounded with fire-walls in a building of ordinary construction, and a transformer gets on fire, the transformer goes, and the oil may get away from you by the melting of the case.

In the case of an emergency such as might call for getting rid of the oil in the transformers, it seems a dangerous proceeding to draw the oil out of the case, when drawn out of the bottom, because in so doing air must get in at the top and there is a chance of an explosion, and that chance becomes greater as more oil is taken out of the case. This question of protection against fire has been carefully considered in the case of oil transformers, with reference to a plant of 50 000 volts and over, where the ultimate installation will mean transformers containing a good many hundred gallons of oil. The different methods of protection against fire were carefully considered and the scheme shown in the diagram finally adopted. The transformer case is built so that it will stand the maximum pressure which an explosion would cause, and all leads brought out through stuffing-boxes which will stand that pressure. To the middle of the top of the tank is brought a pipe running to the sewer and at the bottom of the transformer case is brought a water-pipe which has two valves in series, and between the two valves a drip cock to avoid any possibility of water leaking into the transformer through a leaky valve; the idea being in case of a fire emergency the water will be turned into the bottom of the transformer and drive the oil out at the top. No fire-walls have been installed in that plant although there will probably be some such walls between groups of transformers as an additional protection. As a last resort such an arrangement is about as safe as anything that can be thought of. Another advantage of this arrangement is that it leaves the whole space between the transformer free for a high-pressure wire, which can preferably be a bare one.

C. E. SKINNER:—An element to be considered in the oil transformer is the quality of the oil itself. It is extremely important that an oil be selected which has a flash-test considerably above the temperature at which the transformer will run in normal operation, including overload. At the present time a mineral oil is almost always used and can be obtained

with a great range of flash-tests. One having a flash-test not greatly above the normal operating temperature of the transformer will begin to give off fumes before the flash-point is reached, and these being explosive when mixed with air form a source of danger. An oil should be selected which has a flash-point not lower than, say 175° cent. Such an oil, if properly made, will have practically no evaporation whatever at 100°cent., this being higher than will be found except under the most extreme conditions of temporary overload. Too high a flash-test oil is undesirable on account of the viscosity being so great that the power to carry heat from the transformer to the cooler case is greatly reduced, and on account of its being unpleasant to handle.

Oil as a body cannot be set on fire easily; in fact a torch held to the surface of a body of oil will not set it on fire until the oil itself has reached the flashing temperature, or slightly higher. It is well known in the operation of oil-switches that an arc may be drawn under the surface of the oil and no fire results. This is true even though the temperature of the oil is above the flashing-point when such an arc is drawn, as air is absolutely necessary to the continued combustion of the oil. It is also true that an oil fire may be smothered with comparatively little difficulty, provided the oil is not allowed to spread. It is therefore obvious that a well-constructed fire-proof case with a cover which can be made practically air-tight, placed in a fire-proof compartment with means for draining, as mentioned by Mr. Rice, will reduce the fire-risk of oil-insulated transformers to a minimum. The great advantages of oil in insulating and cooling make it inadvisable on account of fire-risk to attempt to discard oil-insulated transformers, but to provide the necessary precautions to reduce this risk to the smallest possible amount.

H. G. STOTT:—He thoroughly agrees with the view taken by Mr. Rice, that the fire-risk is absolutely proportional to the amount of inflammable material contained in a transformer. When the insurance inspector makes an inspection of the building upon which he is about to issue a policy, he does not merely look at the outside walls of the building but makes a most careful examination of the contents—and the rate depends greatly upon these contents—so that no matter what arguments may be used as to the method of quickly getting rid of the oil and preventing it from flowing out of the case, thus spreading the fire, it should be treated as an extra risk as compared to an air-cooled transformer. A number of instances of serious fires due to oil-cooled transformers have been mentioned to-night, but nothing whatsoever has been said of a fire due to an air-cooled transformer, and the speaker cannot recall ever having heard of such a case where damage was done externally to the transformer through fire communicated by it.

Referring to the general subject of fire-risks and efficiency

of apparatus, he desired to call attention to the importance of having skilled attendants in all power-plants and sub-stations. The difference in paying the men $2 00 a day or $3 00 a day is very small at the end of a year, but the skilled attendant at the higher price will invariably save many times the extra cost of his salary. It seems the height of folly to expend hundreds of thousands of dollars on the very best apparatus which can be bought and then, for the sake of saving a few hundred dollars a year, turn it over to be operated by men of no technical education or special training.

The very best automatic apparatus will soon become inoperative if not given the proper amount of skilled attention. In at least two cases mentioned to-night of fires by transformers due to melting of the solder on the cases, it is quite evident that had there been an attendant present with the requisite amount of knowledge the fire would certainly have been limited to the transformer which was in trouble, instead of destroying the whole station. When anything happens to electrical apparatus there is no time to telephone to any one for information as to what to do; the man on duty must be competent to take care of any emergency which may arise.

P. N. NUNN:—The fire-risk due to the oil transformer is not negligible. In a large, modern power-house filled with expensive apparatus the large amount of oil contained in a full equipment of oil transformers is a constant menace to the entire plant. This is shown by the present record of fires and by the average station record of accidents which might have caused fires. The risk to each transformer, due to accidents within itself, may not be serious, but the combined risk due to many such transformers is very serious, because it applies to the whole investment in the plant. While compelled for the present to use oil transformers, the conservative engineer, in designing high-pressure work, cannot afford to neglect or underestimate their danger, or fail to employ every reasonable precaution, even perhaps some extreme measures, for protection. On this account exception is taken to the spirit of some remarks made this evening. Their effect has been to discredit the importance of this risk, and the protective measures suggested.

Within a few years the Telluride Power Company has lost two complete sub-stations; and while the fires may not have originated in the transformers themselves, the loss suffered, of which the transformers were but a small part, was chiefly due to the oil. It is this danger, to which all surrounding apparatus is subjected by the oil transformer, which constitutes the chief argument against it in favor of the air-blast transformer.

It might be possible to use some highly insulating gas incapable of supporting combustion, which might be circulated, perhaps under pressure, through both transformer and cooling coil.

P. M. LINCOLN:—To start and sustain a fire two distinct ele-

ments are necessary; first, a combustible, and secondly, a supporter of combustion. Bearing this in mind, suppose we analyze the relative fire-risks of air-blast and oil-insulated transformers.

In the air-blast transformer we have present constantly and unavoidably both the essentials necessary to start and maintain a fire, the insulation of the transformer being the combustible and the cooling air the supporter of combustion. The only thing needful, therefore, to start a fire in the air-blast transformer is simply a sufficient amount of heat at any point. In this respect, however, the air-blast transformer does not differ from any other combustible structure, except that under normal conditions the supply of air is by forced draught.

On the other hand, when we come to examine the oil-insulated transformer we find a structure in which the combustible and the supporter of combustion are capable of being easily segregated by a fire-proof wall. Relative fire-risk is not simply a question of the relative amount of inflammable material as Mr. Rice intimates, but it must also involve the question of the probability of a fire being started. The oil transformer, although it contains a considerably larger amount of inflammable material, has the advantage of segregating this inflammable material so that it can be made almost impossible for a fire to start within the transformer, and can also be shielded from a fire outside of the transformer.

The speaker's only personal experience with a transformer fire has been with the air-blast type. This leads him to doubt the practicability of Mr. Rice's suggestion of a fusible link in connection with a damper to shut off the air. In the instance mentioned not only was it necessary to close the damper in the transformer but also to shut off the air and finally to turn the hose on the burning transformer.

In the speaker's opinion the greatest danger in the use of oil-insulated transformers comes from improper installation and consequent probability of the floor becoming oil-soaked. When properly installed, neither the air-blast nor the oil-insulated transformer involves a serious fire-hazard; but if compelled to choose between the two types the speaker would, for reasons set forth above, be inclined to choose the oil-insulated transformer.

C. L. DE MURALT:—He does not agree with Mr. Rice that the greater quantity of combustible in the oil transformers necessarily makes it a greater fire-risk. Transformers as a whole are not by any means the greatest fire-risk in any central station. In Europe, at least in Switzerland and France, the air-blast transformer is considered a considerably higher fire-risk than the oil transformer, and possibly for the following reasons: when air-blast transformers are overloaded, the insulation gets very much heated, and it is just possible that it breaks down somewhere, and takes fire either through the arc or through the heating of the insulation. In the oil transformer the oil forms, so to speak, a sort

of safety-valve, in that an overload will make itself felt only after a much longer time, when the other safety devices will probably have had time to come into play and cut the transformer out. This may be one of the reasons why air-cooled transformers in Europe are generally not used for sizes larger than about 150 kw. Oil transformers can be made almost fireproof, and it is a good plan to put them in separate buildings. This necessarily does not mean complication in the wiring. In the case of hydro-electric plants, which will mostly have to do with high pressures, the building is generally pretty long and narrow, with the units placed on one of the long sides. If the switchboard is placed in the centre of the other long side, it is easily possible to place the transformers in a room right back of that switchboard; similarly, if it is placed along one of the short sides; and in both cases the transformer room will probably not be much longer than the width of the main part of the central station. In both cases the leads from the generators will go to the switchboard, from the switchboard to the transformers, and as there need not be any switches in the high-pressure side of the transformers, they may go straight out. If the need for switches in the high-pressure side is felt, they can as well be placed in the transformer room and actuated mechanically from the switchboard. Thus, the line equipment will be, if anything, simpler than in the arrangement with the transformers in the central station itself.

In looking at the design which Mr. Mershon shows to-night, it would appear that when there is a necessity for flooding the transformers in order to bring the oil out, there is evidently a large fire, and every reason to suppose that the roof will come down and possibly break the oil piping which connects the transformers with the sewer. If this takes place, there may be serious danger of the oil doing more damage than if it had remained in the case. If transformers are located in a separate building, as just described, and placed in strong cast-iron boxes, or else in casings made of boiler-iron, riveted and caulked, and strengthened by angle-irons, and if these cases are well covered by a tight-fitting cast-iron cover, there is absolutely no fire-risk, either from the inside or from the outside, and such a transformer installation may be called as fire-proof as a brick wall.

O. S. Lyford, Jr.:—Before this discussion is closed more emphasis should be laid on a point raised by Mr. Townley. The title of the paper on transformers has naturally led to a discussion which gives the impression that these transformers constitute a very serious fire-risk. The fact cannot be emphasized too strongly, that although transformers are fire-risks these are not risks which cannot be successfully coped with. The speaker does not agree with Mr. Nunn as to the seriousness of the risk of the oil. This transformer subject ought to be separated into three heads instead of two; namely, the oil-insulated, water-cooled transformer; the oil-insulated, air-cooled

transformer; and the air-blast transformer. That they are all good should be emphasized. There is, however, a place for each type, as is usually the case with a number of good things of a similar character. Where water is available for cooling purposes, there is little question that the oil-insulated, water-cooled transformer is the type to be used. Where water is not available, the choice lies between the other two; but there is a distinct field for each. For instance, in a small sub-station, as in the case of an interurban railroad, there may perhaps be a couple of 250-kw. synchronous converters and an equipment of from three to six transformers of moderate size. In such a case the blower equipment is an unnecessary nuisance and the oil-insulated, self-cooling type has the advantage. On the other hand, in a large sub-station, such as one of those on Manhattan Island, there may be 20 transformers or more, and there is a gain by placing the transformers close to the synchronous converters and consequently distributing them throughout the building. Moreover with such a number of transformers the blower equipment is relatively a simple proposition, and all things considered, the advantages are in favor of the air-blast type. Therefore it seems to the speaker that a type of transformer for each specific service should be selected, and having done so it is perfectly possible so to design the plant that the risk of fire is extremely remote. In this day and generation it is seldom that we cannot afford to make a fire-proof building; many things besides transformers justify this precaution. The advantage of a fire-proof building was clearly demonstrated at Baltimore when practically the only two buildings left intact were the new power-station and the sub-station of the electric company, which were fire-proof; the fire could not get into the buildings. An electric plant costs so much money that the percentage added to make the building fire-proof is extremely small. With the surroundings fire-proof and the transformers properly located, the risk, as before stated, is extremely remote.

[COMMUNICATED BY LETTER.]

HOWARD BAYNE:—Mr. Rice's paper refers briefly to the necessity of employing proper means of preventing or extinguishing oil fires. In this connection the writer suggests the consideration of the use of steam as a means of putting out such fires. When properly applied, this has been found by those experienced in the oil business to be the best method of extinguishing an oil fire, particularly when the fire is serious.

Proper arrangements should be carefully planned and must be permanently installed. The transformers should be placed in a separate vault and in case of a large number they might be distributed among several vaults. Suppose each vault was equipped with one or more permanent two-inch steam lines, according to the amount of space in the vault. In case of fire, all outlets, such as doors and ventilators, should be closed and

the steam turned on. Both or either of these operations could be arranged to work automatically. The fire would be smothered in a very few minutes or possibly in less than a minute. The prime requisite is to have a large volume of steam turned into the vault quickly. If the fire is confined to the surface of the oil and the core and windings remain covered with oil, the transformer could be used again with very little, if any, delay.

The efficiency of steam in fighting oil fires is surprising. To illustrate: the company which the writer represents owned an large earthen storage tank at Gladys, Texas. It covered five acres and contained 200 000 bbl. of crude oil which was most inflammable since it gave off naptha vapors and hydrogen sulphide. On August 11, 1903, lightning struck the point of the conical roof. The small hatch at the apex was blown off and a tremendous blaze started. After several minutes the men got the hatch on again and turned steam into the tank. The blaze grew perceptibly less almost immediately, diminished rapidly, and finally went out.

The writer mentions this incident to show what can be done by smothering an oil fire with steam in a case where the fire has most favorable conditions for persisting. Compared to these conditions, those existing when oil in transformers catches fire would render the fire easy to extinguish. With oil-cooled transformers in "fire smothering" vaults the writer thinks the fire-risk would be almost nothing.

[COMMUNICATED BY LETTER.]

W. L. WATERS:—The question of the relative fire-risk of oil-cooled and air-blast transformers can be best decided by considering the different cases of transformers in stations with attendants, and transformers in stations without attendants. And also by considering fires due to internal causes and fires due to external causes.

Considering first fires due to internal causes. In an oil-cooled transformer it is almost impossible to start a fire due to a short circuit or a burn-out in the transformer itself, unless there is nearly unlimited power back of the short circuit. The oil will smother the fire so effectually that usually the mains will go before the transformer catches fire.

On the other hand, in an air-blast transformer a short circuit will turn the interior of the transformer into a blazing furnace, and even though the air supply is automatically cut off the transformer will certainly be totally destroyed unless it is cut out of the circuit. Whether the burning of the transformer itself starts a general fire depends, of course, on the arrangement of the building. If there are attendants present they can take care of the burn-out and can cut out the transformers before the situation gets serious

In the case of an ordinary fire due to external causes the oil-cooled transformer will be completely protected from damage

by the oil, as the latter will not be heated to ignition point and will prevent the heat from reaching the transformer itself. An air-blast transformer in a similar case would probably be ruined, though it might not add much fuel to the conflagration.

In the case of a large fire, the oil in an oil-cooled transformer would be ignited, and on account of the large quantity of inflammable material the results would be disastrous. This might be prevented if attendants were present to draw off the oil, or if automatic arrangements were employed for draining the oil in case of fire. But, in any case an oil-cooled transformer is a very serious risk in a large fire.

Speaking generally, then, an air-blast transformer is at the mercy of almost every fire, no matter how started; and though a single transformer may not add much to the conflagration it will almost always be seriously damaged itself. On the other hand, an oil-cooled transformer is in practically no danger except in a large fire, and then the risk is serious. Generally a set of oil-insulated transformers will be a much safer installation than a corresponding set of air-blast transformers.

[COMMUNICATED BY LETTER.]

IRVING A. TAYLOR:—It appears to be generally conceded that oil transformers are a greater fire-hazard than the air-blast type. Fire is not liable to start inside them, but in the case of an external fire the oil is liable to catch and produce a very hot fire. Internal short circuits are not likely to start a blaze, provided they are well under the surface of the oil, but if the latter is low, or the design is such that the coils are normally near the surface, an arc is liable to reach the surface, produce gas, and so set the oil on fire. The oil level should therefore be well above the coils.

In transformers which are sealed air-tight, a short circuit is likely to set up a sufficient explosive force to blow the cover off or to crack the case, the oil either running out or being thrown out—possibly on fire. Covers should therefore not be air-tight, but should prevent a circulation of the air. One of the greatest dangers from oil transformers is the fact that they are likely to leak under ordinary or extraordinary conditions. In the first instance, surrounding floors, whether of wood or concrete, become impregnated with oil and are very dangerous in the event of fire. Where cases are made of sheet-iron, or jointed with lead, an external fire is likely to open up the seams and let the oil out, with disastrous effect. All cases should positively be made of substantial cast-iron, without joints if possible. Where leaded joints are necessary, the lead should not be depended upon for holding the case together, and the latter should be fairly oil-tight without the lead.

Where oil transformers are used in large quantities, they should, where possible, be installed in a thoroughly fire-proof building used exclusively for the purpose and isolated from other

buildings. They should not be placed in buildings like hotels, or in any room not thoroughly and heavily fireproofed.

It is sometimes desirable to install oil transformers where artificial cooling is not commercially feasible, or where water-cooling is more convenient than air-blast. Otherwise, where the pressure will permit, air-blast transformers are always cleaner in operation as well as safer, and their use is therefore more satisfactory.

Mr. Rice's proposal to use fusible links in air-blast transformers is highly practicable. They should be combined with air-tight dampers, and should be hooked in place so that the dampers may be worked periodically for inspection purposes. While such links would naturally be placed in the draught at the top of the transformer, it would seem that the dampers should be placed at the bottom so as to prevent burning material being dropped into the air chamber and in that way carried to the other transformers.

There should be no inflammable material, either in the path of the air-blast above the transformers or in the ducts, and the wiring should preferably be by lead cables enclosed in tile right up to the transformer. Where it is necessary to use rubber-covered wires at the cable heads in the ducts, they should be thoroughly fireproofed.

[COMMUNICATED BY LETTER.]

NORMAN T. WILCOX:—He believes that where properly installed, the fire-risk with oil transformers is not so great as many imagine. In two cases of fire started by lightning in the step-up transformers in the Canyon station of the Colorado Electric Power Co., he found that they were caused by an arc, which would not have occurred if the oil had been kept to its proper height in the transformer. There was some trouble in putting out the fire, especially on account of the gauze ventilators in the top of these transformers. In one case these spaces were blocked up with waste, which had been soaked in water, thereby choking off the air supply and smothering the flame. In the first case, the engineer of the station threw off the cover to the transformer, which resulted in a lively blaze. This was carried up the wires to the wooden framework almost directly over the transformers supporting the high-pressure circuit-breakers.

He would not use an air-blast transformer on high-pressure work if he could avoid it, as he believes that not only is the insulation better with oil, but the oil prevents the insulating material from baking, drying out, and cracking, and insures a longer life to the apparatus.

[COMMUNICATED BY LETTER.]

A. C. PRATT:—For maximum safety, oil-cooled transformers should be placed in a strong boiler-steel case, with the cover

well bolted on. The latter should have a relatively large flap opening to act as a safety-valve, so arranged that it will not of itself remain in the open position.

There seems to be no doubt that inflammable and explosive mixtures accumulate above the oil in transformers; but the self-closing cover will promptly smother any fire which might be started from this cause. These gaseous mixtures seem to be formed, at least in part, by minute brush discharges in the oil, which break up the mineral oil into light volatile constituents and heavy asphalt-like residue. These effects may be readily produced experimentally, even at pressures below 10 000 volts.

There should also be a considerable air-space to allow for a possible boiling of the oil without boiling over. Such a transformer will most naturallly be of the water-cooled variety, and will always be mounted on a fire-proof foundation. Risk from external fire should be small. A large body of oil in a substantial case, with relatively small exposed surface, will pass through a fire, such as would make scrap of an air-cooled transformer, and be ready for service in a day or two, upon renewal of leads and bushings. Incidentally the transformer cover should be water-proof to such an extent that water from a hose will not fall into the hot oil. As a final precaution, arrangements should be made to drain spilled oil away from the building.

[COMMUNICATED BY LETTER.]

H. A. LARDNER:—In the discussion as to the relative fire-risk of oil- and air-blast transformers, the opinion developed that large oil-cooled transformers in boiler-iron cases with suitable covers and vents were practically fire-proof, provided they could be suitably protected from intense heat from the outside. A suggestion was made that this class of transformers be installed in a pit which could be flooded to within a few inches of the top. While this gives the needed protection, it is an extremely inconvenient method of installation, owing to the necessity of occasionally moving the transformers. On account of the high-pressure connections overhead it is usually undesirable to have a crane in the transformer room, and the most common method is to mount the transformer on trucks so that they can be drawn out of their position and under a suitable lifting device in another part of the transformer house when repairs are necessary.

Naturally the installation of transformers in a pit will necessitate the use of a crane and is therefore objectionable. It occurs to the writer that, as transformers are usually arranged along one side of a room, they might be mounted on trucks as usual and a comparatively light boiler-iron tank installed around them. The back and possibly the two ends would be supported by the walls of the building while the front could easily be held in place by tie-rods. The tank should be provided with an overflow of ample capacity to prevent the water reaching

the leads, bushings, or running into the transformer case. The front of this tank should be made in sections so that a section could be removed and a transformer wheeled out to the repair room when desirable.

It would not be a serious fault if this tank were not entirely water-tight, as water would only be turned into it during a fire, and some leaking would not be objectionable.

The method of protecting transformers by submerging them in cooling water is believed to be good, as there can be no objection to turning water into the tank immediately upon an alarm of fire and the protection need not be left until a last resort. It also seems to be well established that, if the attendants will promptly disconnect a transformer on fire from internal causes and cooling water be applied externally to a suitable air-tight case, the internal fire will generally extinguish itself.

[COMMUNICATED BY LETTER.]

H. F. PARSHALL:—The experience gained in England would indicate that there is no great risk from either type of transformer so long as it is intelligently installed. It has been pretty fairly proved that the oil transformer is more reliable over a wide range of conditions. The principal advantage of the air transformer is in installations like the Central London Railway where an accident to an air transformer brings no risk to the working staff, whereas an accident to an oil transformer might bring about serious consequences. Where, however, the transformers can be installed so that no matter what the occurrence there is no danger to life, the oil transformer is, in the writer's judgment, to be preferred.

[COMMUNICATED BY LETTER.]

R. S. KELSCH:—As regards the relative danger or risk in the use of oil- and air-blast transformers, the writer considers the use of oil transformers extremely dangerous, unless they are installed in isolated buildings. And even then, he would hesitate a long time before being responsible for the installation of several banks of transformers, with each transformer containing from five to thirty barrels of oil.

The writer has as yet been unable to obtain an oil transformer where the case was oil-tight, notwithstanding the fact that the contract specifically stated that in order to be accepted it must be oil-tight. The writer has visited many plants and has not seen an oil transformer that was free from leakage. As a rule, a large drip-pan was placed under the transformers, to catch the leaking oil.

In one instance three 70-kw. transformers for supplying power to induction motors were installed in a building, and during a thunder storm at 2 a.m. one of the transformers failed. After the fire the evidence showed that a short circuit had occurred at a point near the top of the transformer coils, burning a large

hole in one of the cases and allowing the oil to escape, catch on fire, and destroy all three transformers as well as the building.

In another instance, a plant in Montreal was supplied with 5000-volt, three-phase power from a water-power plant. There were three 150-kw. transformers for reducing the pressure to 2000 volts. The building and contents were of a temporary nature. A short circuit ignited the oil that had previously leaked from these transformer cases, and that which had been forced out of the cases by the heat and the entrance of water into the transformers. The entire contents of the building were destroyed, only the walls remaining standing. In this same building, having wooden floors and temporary switchboards, an air-blast transformer of 250-kw. connected solid to the bus-bars, fed by eight 750-kw. generators was completely destroyed. It burned for fully four minutes before the current was cut off, but did no damage outside of the transformer itself.

In another instance in Montreal, two 2000-kw. 25 000-volt, air-blast transformers failed. There were no automatic switches and in order to get the current off it was necessary to telephone the power-house to shut down. This required nearly two minutes, which would be time enough to burn a hole through an iron tank filled with oil and allow the oil, already ignited, to run over the floor; but in the case of these 2000-kw., air-blast transformers, there was absolutely no damage, except to the transformer itself.

From his experience with both types of large capacity, the writer would not use oil-filled transformers, unless compelled to do so. He does not imply, however, that an air-blast transformer in a frame building with a 12-ft. ceiling would be considered safe, but in making the comparison, he refers to the installation of transformers of large capacities in a modern fire-proof station. The danger in one case arising from the possibility of the flames due to the air-blast reaching inflammable material, as against oil escaping from the tank becoming ignited and covering the floor of the station with a sheet of fire. While the oil used in transformers does not ignite readily, and will permit a red-hot iron to be plunged into it without danger, a heavy short circuit will ignite the oil, and in these circumstances becomes a dangerous piece of apparatus.

The writer suggests that air-blast transformers be equipped with a positively air-tight damper to shut off the air. The damper generally furnished is practically useless in the event of the transformer failing, but he has had transformers equipped with dampers which were practically air-tight. The parts were, however, not rough castings, but consisted of a cast-iron frame with brass gates machined so as to make a perfect fit. They are operated by a key hung in a convenient place on the transformer. It may be argued that this introduces a possibility of damaging the transformer, but not to any greater degree than the use of a valve to let water into the transformer or to allow the oil to escape.

[COMMUNICATED BY LETTER.]

H. W. TOBEY:—Many engineers contend that air-blast transformers are the safer of the two types. The preference being due, the writer thinks, to two reasons: first, because the containing tanks of oil-insulated transformers have been made extremely light and constantly leak oil, and in case of fire will often open and allow the entire contents to escape; secondly, because of the use of a poor grade of oil. With substantial tanks and an oil having a high flashing-point, these two drawbacks are entirely removed.

The oil-insulated transformer is capable of withstanding severe and long-continued overloads without injury, while in the case of a short circuit within the winding it is entirely under oil and the arc will be extinguished before injuring more than a single coil. Leads coming from the various coils are always a source of danger unless carefully insulated and surrounded by oil.

Relatively to the ability of oil-insulated transformers to withstand fires due to external causes, the writer can instance an interesting experience of a large power company in the West. At the time of the accident, the transformer equipment consisted principally of a large number of 840-kw. units, all oil-insulated and water-cooled. These were arranged in groups of three each for stepping up from 2300 to 50 000 volts. A fire starting from some external cause spread to the transformer room where it burned for three-quarters of an hour. At the end of this time a pipe line above the power-plant was opened and the place was deluged with water for over eight hours. It would seem after treatment of this kind that little would be left of the transformers except scrap-iron and copper. On the contrary four transformers (which were somewhat beyond the hottest part of the fire) were put back into service without repairs. Others were dried out with current for a few hours and after being filled with new oil were also ready for service. There were only four which actually required repairing. On these the porcelain insulators had been entirely destroyed and the covers were badly cracked. The inside surface of the tanks, together with the coils and cores, were covered with a thick deposit of carbonized oil. A large amount of water had also gotten into the tanks.

The cores were taken down, the coils cleaned, and the outer layer of tape replaced with new. The parts were then reassembled and the transformers put back into service where they are still in successful operation. It is not difficult to imagine what would have become of this apparatus if it had not been immersed in oil.

This brings up an interesting question. Is it good practice, as many maintain, to empty oil-insulated transformers in case of fire?

[COMMUNICATED BY LETTER.]

WM. J. HAZARD:—In an oil-cooled transformer, seal the space above the oil as thoroughly as possible and provide an adjustable vent. Fill this air-space with some inert gas such as carbon dioxide, supplied by a gas generator which will automatically maintain a slight pressure, just sufficient to prevent the entrance of air to the case. The writer believes this would effectually prevent the ignition of the oil gases, and hence add to the safety of the apparatus. The extra complication and the cost of maintenance would be insignificant. The amount of gas necessary would of course depend on the rate of leakage.

[COMMUNICATED BY LETTER.]

E. P. ROBERTS:—In the matter of oil transformers, the practice of the firm with which the writer is connected has been for some time to place such transformers in a fire-proof room, believing that the fire-risk justified the slight additional expense. Our practice has been somewhat of an evolution. The Dayton & Northern power-house, designed in 1900, had a separate room built on the outside of the building and to one side of the generator room. This additional room was fire-proof construction with fire-door between same and the engine-room, with the floor on the same level as the latter. The one sub-station of this road had a fire-proof room built into the balance of the building, which consisted of a synchronous converter room, the fire-proof static transformer room, a storage-battery room, freight and passenger offices, and, above the latter, living rooms for the attendant. The floor of the static room was on the same level as the floor of the synchronous converter room.

In each static transformer room the high-pressure lightning arresters and switches were placed. Since then this has been modified, and for the Dayton & Muncie Traction Co., now under construction, the design is as follows:

For the power-house there is an addition to the building immediately in the rear of the switchboard. The addition has two floors and the whole is of fire-proof construction, using steel, brick, and concrete. The upper floor is on a level with the engine-floor level and herein are placed the high-pressure lightning arresters and switches, while there is a fire-proof door into the engine-room. The lower floor is below the level of the engine-room basement and has a fire-proof door from such basement. In this room are placed the static transformers. The floor is of concrete, with drains, and in case a transformer should catch fire and the oil escape, it will run into the drains and be smothered. But even if the drain should not take it off with sufficient rapidity, it could not run into any other room.

The additional cost of the building is slight, as, in any case, room must be provided for the transformers and high-pressure switches and arresters, and placing these immediately behind the board is convenient, and does not necessitate complication in wiring or in mechanism for controlling the switches.

The sub-stations, of which there are three, are two new buildings and one old one. The new buildings have fire-proof static-transformer rooms with wire towers; the floor is drained and is below the level of the other rooms, and a fire-proof door connects to the synchronous converter room.

The old building is a remodeled warehouse in the center of the town. The static transformers are placed in a fire-proof room in the basement and a tight brick shaft runs from this room to the third floor. The high-pressure wires entering the shaft through large tile ducts, which together with the shaft act as ventilators for the room in the basement, pass from the pole line down the shaft to the transformer room. Cold air is taken from an area way under the sidewalk.

The synchronous converters are placed on the first floor, on foundations extending into the basement and adjacent to the static room. The high-pressure lightning arresters and switches are placed in the static room, the switches being controlled from the switchboard in the synchronous converter room. This is not quite so convenient an arrangement for attention as the other sub-stations, but it is expected that it will prove satisfactory; it was necessitated by the local conditions and the decision of the engineers relative to placing the static transformers in independent fire-proof quarters.

[COMMUNICATED AFTER ADJOURNMENT]

W. S. MOODY:—Some of the gentlemen who have discussed Mr. Rice's paper seemed to have missed the real point which he brought out in this paper. He refers, not to the relative liability of fire orginating in the two types of transformers, nor even the question of relative damage which the transformer is likely to experience should fire develop in it, but the relative "fire-risk" of a *station* equipped with one or the other type of transformer. It is not necessary in considering this point to assume that one or the other type of transformer is inherently the safer or even that fire originates in the transformer at all. The simple question is, how much does the addition to a certain building of a certain small amount of inflammable material such as is contained in the air-blast transformers, increase the fire-risk on the building and contents as compared with the addition to the same building of transformers containing several hundred barrels of oil.

The question seems hardly to admit of discussion. The chances of a fire external to the transformer communicating itself to the interior is also slight. But granted a fire can originate somewhere and that it may set the insulating material on fire beyond control, then will not a few pounds of varnished wrappings constitute a perfectly negligible risk as compared with many barrels of oil?

DISCUSSION ON THE USE OF GROUP-SWITCHES IN LARGE POWER-PLANTS.

ALEX DOW:—As to group-switches; the speaker considers that the separation of not only the feeders but generators into groups is now accepted as good practice. The drawing illustrating Mr. Stillwell's paper showed a condition normal in some plants but not representative of general practice. The accepted practice is, according to the speaker's observation, not to operate all the high-pressure generators in multiple but to separate the generators either individually or into groups and to give to each generator or group of generators its own group of feeders. The plant operated in multiple but only through the low-pressure distribution system—not on the high-pressure bus-bars; excepting, of course, that generators were put in multiple for the purpose of transferring load or taking machines in and out of circuit. The separation of generators and feeders into groups is indicated as advisable excepting where the transmission system has considerable resistance and inductance. A most notable exception which—like the tied-up air-switches—has also come recently under the speaker's observation is the Pacific Coast practice of running not merely several generators and feeders but several power-houses in multiple. The feeders and the tie-lines between power-houses are overhead and have high inductance, either natural or artificial. The frequency is high. Such a Pacific Coast system always "hangs on" to a short circuit. In one of these systems the established rule for dealing with a short circuit is to pull the field-switches of all synchronous apparatus—generators, synchronous converters, and motor-generators—excepting at one generating station. None of the apparatus is cut off from the system. The obvious result is that the remaining power-station has to supply a very large lagging current; the e.m.f. falls, and the short circuit breaks; whereupon the operators at the other power-stations and at the sub-stations re-excite the fields of their machines and normal conditions are re-established. A high-pressure system which can be dealt with in this manner has no occasion for group-switches. When, however, the conditions permit the concentration of a tremendous amount of energy on one fault, the group method is indicated and is already accepted as standard.

RALPH D. MERSHON:—The reasons given by Mr. Stillwell for the use of group-switches undoubtedly had great weight at the time the plants referred to were designed. That was when the oil-switch had not demonstrated its reliability, so thoroughly as it has now. In the present state of the art some of the reasons do not seem to stand very well. The oil-switches for pressures up to 10 000 which are constructed to-day seem at least as reliable, if not more so, than the apparatus which they control. If that is the case, it would seem that one is not justified in putting a number of switches in series. As regards the

ease with which the load can be thrown off the power-house, that can be taken care of by having tripping arrangements which will operate a group of switches which can be tripped at once. As regards the transferring from one set of bus-bars to another, there is a great advantage for the group-switch if the transferrence must be made quickly. If time can be taken to do it, a selector-switch might be used instead of two oil-switches.

H. G. STOTT:—Referring to Mr. Stillwell's paper upon group-switches, the speaker considers the group-switch as a species of insurance. The more valuable the contents of a house, the more insurance a man wants upon it and its contents; and in the same way the more expensive a plant is and the more important the service supplied by it, the more important it becomes to take every possible insurance against a shut-down due to any cause, as a shut-down of no matter how short a duration has a most disastrous moral effect upon the entire business connected with it. As a matter of actual experience of more than two years with over 160 oil-switches, the speaker has never yet had a single case where they failed to open the circuit when required. In some short circuits over 100 000 kw. were concentrated, so that certainly they have had a severe enough test to prove their reliability under all conditions. However, it would require a great deal of courage to advise leaving out group-switches in plants above 35 000-kw. capacity of generating apparatus.

In regard to Mr. Dow's statement as to the operation of plants without generators being in multiple or upon groups of feeders, the speaker does not know of any plant of any size that is operated in this way. In all large plants in New York City with the exception of the New York Edison Co., everything is operated in multiple. He believes the New York Edison Co. operates its station in two sections, but in each of these sections several generators are operated in multiple.

LEWIS B. STILLWELL:—In the discussion, two things had particularly attracted the speaker's attention. One was the remarkable short circuit Mr. Scott developed when he endeavored to induce Mr. Nunn to open an air-switch; the other was the interesting and original design which Mr. Mershon had adopted in the important plant at Montreal. This design the speaker considered well worthy of careful study, although he had not definitely formed his opinion in respect to it; it impressed him as being a substantial addition to engineering practice in the matter of oil-insulated transformers.

So far as the subject of group-switches was concerned, he was glad to know that Mr. Stott, who is now in responsible charge of the operation of the Manhattan plant, agreed with him in believing their use to be advisable. Obviously, their use or non-use depended primarily upon the degree of importance attached to an interruption of service and there was one

way to state the case in respect to the particular plant to which he had referred in his introduction which was perhaps stronger than any which he had used; viz., by comparing the annual cost of the auxiliary group-switches and their bus-bars with the revenue earned by the system in a short interval of time. As he had stated in the introduction, the cost of the group-switches with bus-bars is not over $2000 a year, allowing 5% for interest and 5% for maintenance, while the gross receipts of the system in rush hours often exceeds $5000 an hour. When the subject is looked at in this way, it is evident that the additional precaution is well taken. The speaker did not agree with Mr. Mershon in regard to the use of group-switches. The speaker understood Mr. Mershon to say that if by using a single switch for each feeder the risk of interruption of service by reason of switch failure was reduced to a point where it did not exceed the risk of interruption due to failure of the apparatus controlled, it would be unwise to double the switches. The speaker felt that this view was not correct and pointed out, for example, that if in a given plant using no group-switches six interruptions of service should occur in the course of a period of five years by reason of dynamo failures and six interruptions by reason of switch failures, it would be wise to use group-switches which might be reasonably expected to reduce the interruptions due to switch failure and so reduce the total interruptions of service.

[COMMUNICATED BY LETTER.]

WILLIAM B. JACKSON:—In determining the best arrangement of the switching equipment for a power-plant, two prime considerations and one of lesser importance must be the deciding factors. These are in order of importance: the reliability of service that may be expected from the system under consideration; the convenience and flexibility of operation; and the cost and depreciation of the equipment.

The use of duplicate bus-bars throughout electric power-plants as well as two single-throw selector-switches for transferring from one set of bus-bars to the other in place of one double-throw switch, has come to be recognized as standard construction.

No single arrangement of switching devices can be laid down as the perfect one for all plants. In general, however, the most reliable service is attained by bringing directly to the main bus-bars all of the generator and feeder circuits. Each circuit in this case should be supplied with a master-switch by which it can be disconnected independently of its two selector-switches. With such an arrangement of circuits no local accident which may occur beyond the main bus-bars and their connections can interfere with more than one circuit. Also no switch need be of greater capacity than that of its circuit. As the quantity of energy which must be handled by a switch has much to do with the reliability of its operation, this latter consideration is of im-

portance; especially as the individual circuits of large power-plants usually transmit as much power as can be conveniently handled by one switch.

In a group-switch arrangement as described by Mr. Stillwell the reliability of service is not so great as in the arrangement above described, since it introduces auxiliary bus-bars and associated connections, an accident to which will disturb the operation of all of the circuits in the group; also by the addition of currents of several circuits at the group-switch a troublesome switching problem is engendered.

By carrying each of the circuits directly to the bus-bars a more convenient and flexible system of switching can be arranged. The individual circuit, which is the natural unit of distribution, is duly recognized in this arrangement. By this system each circuit, whether it be a generator circuit or feeder circuit, has its own individual group of switches the operation of which will effect its connections alone, and it may be connected to either or both sets of bus-bars or disconnected therefrom with complete independence.

Although more switches are required for a reliable system for individual circuit control, yet the fact that each switch has to do with its own circuit alone permits of a switching system of great simplicity, and of perfect flexibility. The controlling table and instrument board can be arranged so that each circuit may have its own individual sections upon which all controlling levers, or switches, and all indicating instruments may be arranged so that the exact condition of the circuit can be instantly seen, from the observation of a single section.

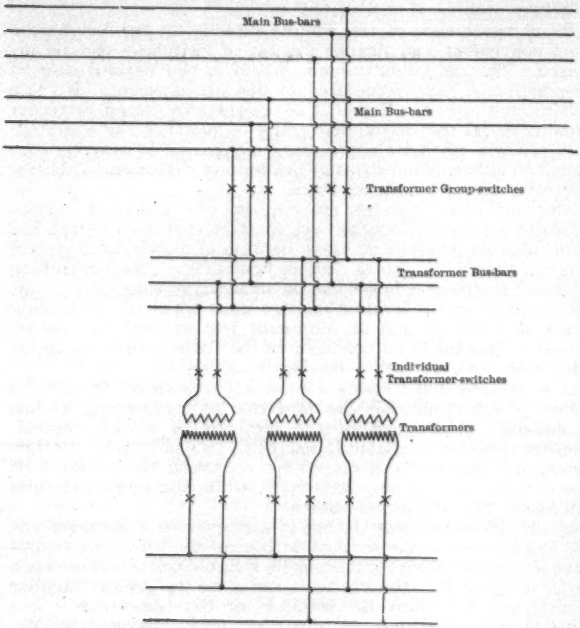
It is entirely unnecessary to use a group-switch system to permit of simultaneously disconnecting or transferring groups of circuits. With most of the methods of switch control, whether they be mechanical, electrical, or pneumatic, master-control can readily be arranged for operating the switches of two or more circuits simultaneously, while the several circuits still retain their individual control.

In the element of cost the use of a group-switch arrangement will usually reduce the actual first cost of the switching equipment as compared with a thoroughly reliable system where each feeder is brought to the bus-bars, owing to the greater number of switches that must be installed for the latter case. For instance in the arrangement described and illustrated by Mr. Stillwell, six circuits are handled by use of six single-throw circuit switches and two group-switches. To control six circuits where each circuit is brought to the bus-bars, twelve selector-switches and six master-switches would be used.

The matter of depreciation will also favor the group-switch arrangement owing to the less number of moving parts therein contained though this will not be so great as might be supposed, since it is necessary to introduce the higher-capacity switches in the group system as already referred to.

The cost of the switching devices required for any power-plant is exceedingly small as compared with the total cost of the plant, and a slight gain in reliability, ease and flexibility of operation will more than compensate for any added cost and depreciation that may be occasioned by the bringing of each circuit to the main bus-bars.

The plant referred to by Mr. Stillwell is an unusual case in which each set of feeders that are controlled by the group-



switches may apparently be considered, under ordinary circumstances, as a multiple-feeder carrying current to the same set of sub-station bus-bars. Under such conditions it would always be necessary to transfer all of these circuits simultaneously. It would seem that a more perfect result might be attained by arranging the system throughout so that all of these feeders would not of necessity be operated from the same set of main bus-bars.

In power-transmission plants, where step-up transformers are employed, a use of switches is made that may properly be considered in this discussion, but which is somewhat different from the group-switch arrangement described by Mr. Stillwell. In all plants where Δ-connected single-phase transformers are used it is desirable to be able to disconnect any one transformer without disturbing the others. Also, it is quite important that in changing from one set of bus-bars to another all of the transformers be transferred simultaneously. It is therefore quite desirable that the individual transformer circuits should be provided with their own disconnecting devices while transformer group-switches be arranged for transferring the Δ from one set of bus-bars to another. The arrangement is shown in the accompanying sketch.

Taking everything into consideration, it is the opinion of the writer that the arrangement of group-switches as described by Mr. Stillwell is one of limited usefulness, and that an arrangement wherein the individual circuits are brought directly to the main bus-bars is usually to be preferred.

[COMMUNICATED BY LETTER.]

IRVING A. TAYLOR:—Mr. Stillwell has enumerated, in very concise form, the several advantages in favor of group-switches. No. 1 is that they provide an additional means of breaking the circuit in case of failure in the feeder-switches. Nos. 2, 3, and 4 cover advantages of group operation.

It seems as though the latter class of advantages might be obtained as readily and more simply and cheaply by the use of multi-point control-switches, used in parallel with the ordinary ones; as group operation could be easily obtained in this way.

Advantage No. 1 was certainly very strong at the time the plants in question were designed, but, as Mr. Stillwell says, is not so important to-day, on account of the reliability of the oil-switch, but yet has some weight.

There are few plants, even of great magnitude, where a complete shut-down for five minutes (sufficient to clear a defective switch), once a year or two, is of sufficient importance to warrant the expenditure of several thousand dollars to prevent it. Probably large lighting companies, having a low-pressure network, are an exception to this, on account of the difficulty of starting up after a shut-down. With this exception, it looks very difficult to decide in favor of group-switching at this point of time, and this applies particularly, as inferred by Mr. Stillwell, as plants are smaller.

Another point that has to be considered in arranging feeder- or generator-switches is that few men of sound judgment would allow a man to touch lines, or even the coils of a generator, if an open oil-switch were the only thing between the man and death. The risk is not much; but life is too important to assume it. An oil-switch handle may be open, but one line may be

short-circuited in the switch, or the latter may be broken. Therefore, some kind of an air-switch should be provided in series with each feeder or generator oil-switch, for use on such occasions. An ordinary air-switch having short break, but provided with barriers, seems to be very proper for the generator circuit. On feeders, it seems as though a fuse-block could be used to advantage, as it will not cost materially more than the air-switches and will give additional means of automatically disconnecting the circuit, as well as fulfilling the above functions. In any case such switches or fuses should be installed between the bus-bars and the oil-switch.

Expulsion fuse-blocks with spring tension have proved to be very reliable on ordinary power and lighting circuits, provided they are occasionally inspected. It would be interesting to know whether such fuses are really reliable for breaking high currents to synchronous apparatus, as this is the worst possible condition. The writer understands that this fuse-block has not the same vital objection as the air-switch, in causing an abnormal rise of pressure or breaking the circuit. It may seem like a step backward to propose fuses, but if the objections noted are set aside, it would seem as if this were their proper field.

[COMMUNICATED BY LETTER.]

GILBERT WRIGHT:—The writer suggests that in place of the arrangement of group-switches, selector-switches, and bus-bars shown on the plan submitted by Mr. Stillwell, one set of main bus-bars be used instead of two, and that the feeders be tapped directly from this one set of bus-bars, the feeders to be controlled electrically, singly, and in groups. This method of control; that is, single and group, is very readily accomplished by installing one control-switch for each feeder and one master-switch for each group. This reduces the total number of switches by 32, eliminates one set of main bus-bars, eight sets of group bus-bars, with the necessary wiring between the switches and bus-bars.

Mr. Stillwell says that the group-switches and the group bus-bars in this station cost $20 000. Estimating the cost of the 16 selector-switches for the generators and the extra set of main bus-bars, with the necessary wiring, to cost another $20 000, would make a total saving of $40 000. By spending, say, $10 000 of this in improving the feeder-switches and in additional insulation and fireproofing of the main bus-bars and wiring, and on the additional control-wiring necessary to control the feeders singly and in groups, it is the writer's opinion that a greater factor of safety on the whole plant would result and that the same facility of handling changes in load would be obtained as by the plans described in Mr. Stillwell's paper.

The writer looks upon group-switches, duplicate bus-bars, and the necessarily complicated wiring for connecting same in the power-house, as so much insurance on the continuous opera-

tion of the plant; this insurance placed in small amounts, in a great many places and at a cost much too large in proportion to the results obtained. It will be seen that a possible saving of $30 000 could be made on this plant by the method described above.

The writer would suggest for general station practice to use as few switches, bus-bars, and as little wiring as possible, and make switches larger, more rugged, and with capacity to handle not once but many times the maximum load that they may under any conditions of service be called upon to handle.

[COMMUNICATED BY LETTER.]

JOHN B. TAYLOR:—The writer agrees entirely with the author of the paper, that no hard and fast rules can be laid down as to the conditions under which the use of the group-switch is, or is not, advisable. Apart from the question of mere additional cost, the following features in connection with the plant have some bearing on the matter:

(a) Pressure of the system.

(b) Number of cables or independent circuits supplying energy to each of the sub-stations.

(c) Liability of trouble occurring on any of the conductors or cables, requiring disconnection from the network.

(d) Reliability in operation of the high-pressure switching apparatus used, as shown by behavior of a number of switches in practical service.

(e) System of connection of low-pressure distribution; that is, with one sub-station out of service can cars be kept in operation adjacent to this sub-station, through power supplied by other sub-station?

(f) Character of service,—whether city work or interurban.

Taking up in order the various arguments given in the paper:

I. "Additional means of opening a feeder-switch that fails to open its circuit when operated for that purpose." The need of two switches in series for all circuits, both generators and feeders, connecting to the main bus-bars, must finally be largely a matter of personal opinion, based mainly on what the designer of a new system has observed or can learn from others regarding the behavior of the high-pressure switch it is proposed to use, under severe service conditions.

II. "It affords means of reducing aggregate load upon the power-house in case of necessity, more rapidly and otherwise less objectionably than the usual method of cutting off individual feeders." It is evidently advantageous to cut off all energy supply to a single sub-station without the necessity of locating and individually operating five or six controlling switches located at a greater or less distance from each other. While the use of the group-switch and the bus-bar gives the complete control of power supply to each sub-station through an individual switch, it should be noted that this same control could be obtained at

an expense extremely small, compared to the cost of a group-switch and additional bus-bar, by bringing to a central point the wires which control the opening of the feeder-switches. A single motion of a gang-switch would simultaneously open all of the four or five or more feeders supplying the sub-station to be cut out.

III. "Where duplicate main bus-bars are used, it facilitates transfer of load from one set to the other . . ." Obviously for the Manhattan station, fewer switches are necessary with the group bus-bar than would be required if two switches (one for each bus-bar) were supplied for each of the feeders. He thinks that in many plants the extra expense and complication of a duplicate bus is unnecessary and undesirable. In most cases, a single set of bus-bars, properly installed, with knife-blade disconnecting-switches, will be found cheaper, simpler, and quite as reliable. With very few exceptions, a spare bus-bar when installed is made use of only to allow men to work safely upon, or near, the regular bus-bar. The disconnecting-switches above referred to need occupy no additional space, and a judicious placing of same, to suit number of generators, number of feeders, character of load, etc., will permit cutting out a portion of the bus-bar, so that same may be handled with safety.

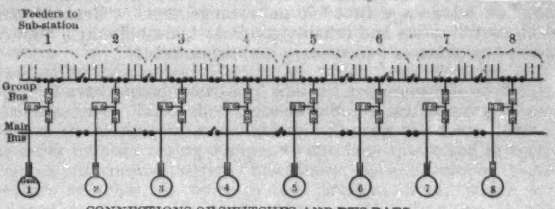
IV. "The grouping of the external feeder circuits in group units bearing a simple fixed relation to the generator units establishes a symmetry and proportion most useful to the operator, particularly in times of emergency." This symmetrical relation between number of generators and groups of feeders, is obviously not necessarily a general case, and while the proportion will hold more or less closely in most cases of city work, the relation between the number of generating units and outgoing feeders in a power-plant supplying an interurban system or a portion of a main trunk-line will be quite different. In the case of the city system, each sub-station is supplied by a number of independent cables, while in the general case of the interurban system or trunk-line, there are relatively very few feeders, which may supply several sub-stations, passing in and out of the stations intermediate between the generaing stations and the most distant sub-station. For service of this character, there could in many cases be but two groups, each consisting of the line either way from the power-plant. In the latter case, a group-switch is likely to be of very little benefit.

Regarding the two arguments cited by Mr. Stillwell against the use of the group-switch; that is, additional apparatus which may of itself increase the risk of interruption of service and the cost of installation and maintenance, the writer comments as follows:

The advantages to be gained through a complicated system of connections and switches equipped with all the various automatic and protective devices for overload and reversal in direction of energy transfer, with arrangements for instantaneous operation and adjustable time-limit, are always more plainly

evident on paper than in a plant in practical operation. It is better to err on the side of simplicity, giving the reduced amount of apparatus rigid inspection and attention, than to go to the other extreme of constructing a cumbersome switching arrangement, which is flexible only in theory, and confuses the operators in times of emergency by offering a number of possible combinations, each of which may be right, but no one of which is the only thing to be done, and that in a hurry.

Referring to the diagram of bus-bars and switches in the 74th Street station of the Manhattan Railway Company, it will be noted that each of the group bus-bars is fed at a single point and has no sectionalizing-switches. Now this means that no work can be done on a group bus-bar without entirely shutting down a sub-station, and any trouble occurring on this bus-bar or on the connections between it and the switches, will cause a complete



CONNECTIONS OF SWITCHES AND BUS-BARS FOR A LARGE POWER PLANT

Knife disconnecting switch
High-pressure oil-switch

NOTE: A single conductor of three-phase system is shown in diagram

shut-down of a sub-station, until the trouble can be repaired or cleared. This criticism could easily be avoided by feeding the auxiliary bus-bar at the middle instead of at one end, and inserting knife-blade sectionalizing-switches either side of the feeding point. Such an arrangement would permit the operation of the sub-station with half of the feeders, while work might be done on the other half of the group bus-bar. A still better arrangement would be to tap one of the group-switches at each end of the group bus-bar, knife disconnecting-switches being inserted in the middle of the group bus-bar.

In the accompanying sketch, the writer has drawn up an arrangement of switches and bus-bars which is essentially a single main bus-bar and a series of group bus-bars, which, however, may be interconnected to form a reserve main bus-bar in case of trouble or to facilitate work upon the main bus-bar. It will be noted that this

arrangement in its normal connection retains the group switch and also provides two switches in series between each generator and the bus-bar. The writer has shown the same number of generators and groups as are shown in the Manhattan diagram, and it will be noted that sixteen less high-pressure oil-switches are required. Oil-switches might be substituted for the knife-switches connecting the different group bus-bars and also in place of the knife sectionalizing-switches in the main bus-bar, but the writer considers the use of oil-switches at these points unnecessary.

[COMMUNICATED BY LETTER.]

H. F. PARSHALL:—So far as the writer is aware the only installation in Great Britain using group-switches is that of the Glasgow Corporation Tramways Department, the sole reason at the time being to safeguard against the failure of individual switches. With absolutely reliable switches there would be no possible advantage in such an arrangement. Granted that each switch safely and reliably controls its own circuit a duplication of switches is unnecessary and undesirable.

DISCUSSION ON "OIL-SWITCHES FOR HIGH PRESSURES."

C. C. CHESNEY:—(A) It is quite apparent that in the rapid evolution and in the perfecting of electrical machinery for power-stations, switch and switch-control design have been more or less neglected. On account of the great importance to all power stations of good switching mechanism, the reason for this neglect is rather difficult at this date to understand, although it is evidently more or less due to the apparent simplicity of a rather difficult problem. While dynamo, engine, and wheel design have been reduced to an almost exact science by the best talent of the engineering profession, the switch and the controlling mechanism have been refused the attention they deserve, although it may be safely stated that in power-stations of this country there are more shut-downs due to defective and inadequate switching mechanism than to any other one cause. Mr. E. W. Rice, several years ago in his paper on "High-Potential Control" pointed out the inadequate means at hand at that time for controlling and switching currents of large volume and pressure. In the same paper he described certain switches designed by the General Electric Co., which from extensive tests were believed would meet any and all requirements of heavy station-service. Since then these switches in actual service have fulfilled the designers' expectations. During the same period, the other manufacturing companies specially interested in high-pressure alternating-current machinery have developed high-pressure switches, on more or less different lines, which are believed to be equally good. However this may be, it can hardly be expected that the design of any of these switches is final and that there is no room for further improvement. The following notes are therefore offered in order to outline the more important features and essential elements which have made some of the later switches successful, but without any attempt to describe any particular make of switch or describe any particular switch design.

(B) Types: on American high-pressure transmission lines there are four general types of switches now in use:

1 Switches designed to break the circuit in the open air.

2 Switches designed to break the circuit in an enclosed air-space.

3 Switches designed to break the circuit with the aid of an enclosed metal fuse.

4 Switches designed to break the circuit under oil.

Type No. 1. The large amount of space required by this switch in order to be certain that the arc will be broken makes its use impossible except in rare instances and then it can be used with safety only when the line pressure is comparatively low, for the reason that a circuit containing inductance and capacity may have very high-pressure oscillations set up in it by an open air arc, unless the current is broken at zero value. The result of the increased pressure is likely to be the destruc-

tion of the insulation on some part of the system, probably that of the transformers.

Type No. 2. This switch is a decided improvement over Type No. 1, as far as the amount of space occupied is concerned, but its effect on circuits containing inductance and capacity is very little different from Type 1, so that there will be the same oscillatory rises of pressure and the same destruction of the insulation on opening the circuit. In addition, the explosion on opening heavy currents with this switch is at times so terrific as to endanger not only the switch itself, but all delicate instruments in the immediate neighborhood.

Type No. 3. Two forms of this switch has been more or less used. In the first form the fuse is connected in parallel, and in the second in series with the current carrying parts of the switch. The first form is limited to low-pressure circuits, because of the total unreliability of the enclosed fuse on comparatively high pressures when the circuit is fed from large central stations. The second form operates through the severing of a metal fuse within an enclosing tube filled with powdered carbonate of lime, or some other non-conducting powder. The end of the fuse is drawn through the tube by the moving arm of the switch and the circuit is opened without serious commotion if the switch has been well designed and care has been taken properly to fill the tube. The switch will open safely almost any circuit at almost any pressure, but like the open air-switch is limited by the amount of space required, while the powder set flying by the explosion of the arc is a decided objection if there is any moving machinery in the same room.

Type No. 4. This type of switch has within the past year been almost universally recognized as the only switch to be used for high-pressure work, for the reason that it can be made in compact form at reasonable cost and when properly built will disconnect from the generating system with certainty and safety any circuit under any condition of load, even a low resistance short circuit. Contrary to general expectations, it has been shown by a number of experiments that the opening of a circuit by an oil-switch is not a *quick break*; the oscillograph shows that the effect of the oil is to allow the arc to continue for several periods and then, as a rule, to break the current at the zero point of the wave. As a consequence, the opening of any circuit with oil-switches is rarely accompanied by destructive rises of pressure. The true reason for this fortunate action of the oil-switch is rather difficult to see. One prominent experimenter has attributed it to the "practical incompressibility of the oil, and, in consequence, the gas bubble which is formed at the terminals of the switch is under an enormous pressure and holds the arc up to the next zero value of the current. At the next zero value of current the liquid pressure blows out the arc." Another holds that by the breaking up of particles of oil by the arc, a high resistance conducting strata is formed

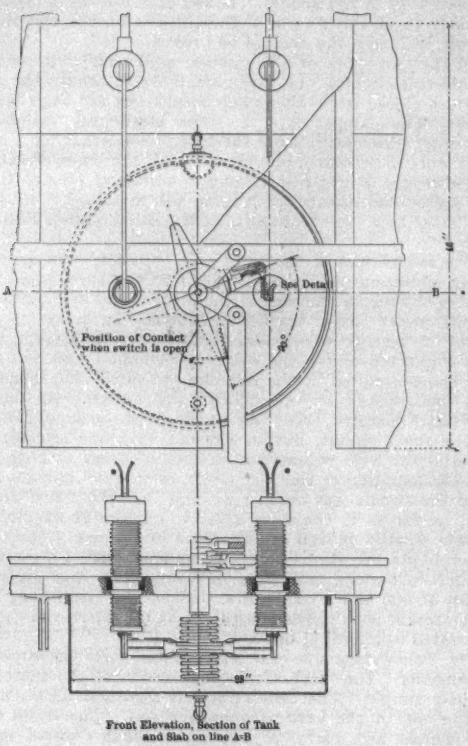
between the terminals of the switch, which allows the circuit gradually to discharge itself. It is probable that both of these phenomena may simultaneously enter into the action, because it is true that an oil-switch creates less fuss in the oil if it is opened slowly; but it is also true that an oil-switch for 40 000 or 50 000 volts must have a depth of oil over the terminals of at least four or five inches. If less depth of oil is used, the oil is likely to be thrown out of the oil pots, on the opening of the circuit, although the arc will be broken.

Of the two types of oil switches, used on 20 000,- 30 000-and 40 000-volt circuits, one, the plunger type, breaks the arc in a vertical plane, while the other breaks the arc in a horizontal plane. The plunger type has been used quite extensively in the larger power-stations of the East. The other form has been used more particularly by one or two of the larger Pacific Coast long-distance power-transmission companies. Some time ago the writer had an opportunity to test thoroughly a switch of the latter type on the circuits of the Bay Counties Power Company.

The switch was of the three-pole type and was arranged to break simultaneously the three legs of the three-phase circuit. During the regular running of the plant it had given satisfactory results under rather trying conditions. In order more thoroughly to test the arc-breaking qualities of the switch, one pole was connected across the main transmission line and the line was short-circuited at the full line pressure. The short circuit was then opened by one pole of this switch. As the switch was hand operated, there was no record of the exact time length of the short circuit, but it was not over one second. These experiments were repeated a number of times at both ends of the 150-mile line of the Bay Counties Power Company. Each time the circuit was opened without disturbance of any kind, and, as far as it could be determined, the short circuit was opened equally as well at either end of the line. During these experiments the Bay Counties Company were supplying their regular customers, and were operating at a line pressure between 45 000 and 46 000 volts. All of the alternating current generators at both power-houses were in operation and the output amounted to about 11 000 kw.

Fig. 1 shows one pole of this switch and gives the approximate dimensions. The mechanical construction of the switch is extremely simple. The contact-arm is mounted on an insulator at the end of the vertical operating rod. The outer ends of the contact arm carry fingers, which make contact with terminal-blocks on the ends of the studs which pass through the porcelain insulators to the line. It will be noted that each pole has two breaks in series, each about nine inches long. The switch was operated by rotating the operating rod which moved the contact arm through an angle about 90°. The oil-tank was 28 inches in diameter and there were about five inches of oil over the

contacts. During the test the cover of the switch was off so that the breaking of the arc could be observed. At each break there was a small arc formed at the terminal-blocks, but there was only a very slight elevation of the surface of oil immediately over the arc.



Front Elevation, Section of Tank and Slab on line A-B

FIG. 1.

(C) On the assumption that the oil-switch, in the present state of the art, is the only switch to be used for high-pressure work, the following points of construction will bear consideration after the particular form of oil-switch has been selected:

1 Rating: The performance of the switch under abnormal conditions of a low resistance short circuit should be considered as well as the capacity of the switch under normal operating conditions.

2 Oil: Any good paraffine oil will answer, but it should have about the following characteristics:

Flashing point	215° cent.
Fire Test	250° cent.
Specific gravity	0.865
Viscosity	———
Acid	None.
Alkali	None.
Evaporation	Negligible.

3 Insulation: The insulators and insulating bushings should be either glass or porcelain. The switch should stand a breakdown test between the live parts and the metal case and framework of at least twice the working pressure. The external terminals should be far enough apart, or sufficiently well insulated, so that there can be no possibility of the current striking across through the air from terminal to terminal.

4 Location: Oil-switches should be placed away from the switchboard as well as the generating and transforming apparatus. Each pole should be placed in a separate fire-proof cell, so that by no possibility can an arc or explosion in one cell be communicated to another or to the neighboring machinery.

5 Method of Operation: All switches should be either magnetically or electrically controlled from a central switchboard, and all the poles of a switch should be operated simultaneously. It is also desirable to equip each switch, especially if it is automatic, with a time-element attachment, so that the circuit cannot be opened for at least a second after the operating mechanism is set in motion.

F. A. C. PERRINE:—The speaker wishes to describe some experiments tried last fall with three oil-switches operating on the same principles as the one Mr. Chesney describes. The three switches were connected up at Mission San José in California, 98 miles from the power-plant of the Standard Electric Company, and the experiments were carried on during the night so that command of the entire generating station could be had. This station contained four 2000-kw. machines. A single handle controlled all three switches so that they opened simultaneously. The three-phase line was first connected through the switches, and the three phases short-circuited at the other side of the switches, thus putting a switch in series with each break. The line pressure was 40 000 volts. The switches were opened and closed about six or eight times that night. Then the work was shut down until the next night, when the switches operating as a short circuit between the wires of each phase could be connected, so that each switch formed a short circuit on a phase, the three

switches short circuiting the entire line, which is very much more severe service than in the former connection. The line was short-circuited and the switches were opened several times, first opening the switches quickly after they had been closed, and afterward holding them in short circuit. The switch operated successfully, the machines held the speed and the voltmeter showed the pressure was held up. The ammeters went off the scale at 12 500 kw. Finally the experiments were discontinued because at the power-house end of the line the lightning-arresters arced over. These were a series of the so-called Dutch-horn lightning-arresters which, especially for the experiments, were set 4.5 in., so that from line to line the gap was nine inches. The arc in almost every instance when we opened the switch went across these lightning-arresters and finally they were destroyed, the pole head was destroyed, and the No. 0 ground wire was entirely fused. The superintendent said that the appearance at the station was as though the sun had come down in the back yard. The interesting thing was that those switches did not fail to open the circuit on any one of the experiments, and the experiments were only discontinued on account of the danger to the generating and transformer apparatus due to the apparently high-pressure as shown by the current jumping across nine inches of open air space.

ALEX DOW:—In his opinion the oil-switch had definitely arrived—it was not merely coming. In Pacific Coast installations visited within the past thirty days he had found the air-break switches carefully tied up so they could not be operated; and in series with them, oil-break switches which were regularly used. This substitution of a nine-inch oil-break for a six-foot air-break was general on the Pacific Coast.

RALPH D. MERSHON:—Referring to Mr. Hewlett's paper, the speaker did not agree with Mr. Dow that the oil-switch has necessarily come. It has come for some pressures, but not necessarily as yet for 30 000, 40 000, or 50 000 volts, as any construction which in the present state of the art means going into cables with high pressures is objectionable. With such oil-switches as the speaker is familiar with, this is necessary or else a large amount of space for their wiring and installation becomes necessary. If an oil-switch could be put up in the roof truss of the building, being made as it were a part of the high-pressure conductors,—then it seems that the oil-switch would be a very advantageous piece of mechanism to use in connection with high-pressure plants, but until that is done it does not appear attractive.

C. F. SCOTT:—So much has been said about the oil-switch and so little that was favorable about the air-switch that the speaker thought of asking Mr. Nunn to say a few words on the subject. The air-switch a few years ago was introduced in high-pressure work when there was no oil-switch for that work, and it seems it still has a large field of its own in places where the

pressures are high and the amount of power, as for instance in small sub-stations, is small; where the oil-switch, as developed now, will be too expensive to install. In the first high-pressure plant of 40 000 volts, installed at Provo, Mr. Nunn had certain air-switches which it is understood rendered excellent service.

P. N. NUNN:—The impression is conveyed by Mr. Scott that a defence of the air-switch may be expected. The high-pressure air-switches at Provo are rapidly being replaced by oil-switches. This is in order to avoid the line disturbances caused by air-switches, and also in order to substitute the automatic feature of the oil-switch for the fuses necessary with air-switches. It is true that oil-switches are very expensive, but, while a reduction in cost will be most welcome, even at present prices, they will undoubtedly be used in all future high-pressure work.

C. L. DE MURALT:—The speaker's firm uses both oil-type and air-type switches, the former in preference in all important installations, at least in the main leads. But there are cases where it would be very expensive to have oil-switches in every single place where the current may have to be interrupted at some time or other. Therefore, in places where such interruptions occur only once in a great while, or only in cases of an emergency, he sometimes, when economy is necessary, employs switches which resemble somewhat the horn-type of lightning-arrester. The main part is in fact built exactly like one of these lightning-arresters, the air-gap being bridged by a terminal part which, when the switch is actuated, is drawn away. The arc then breaks itself by drawing toward the upper ends of the horns, which are wider apart. The current of a 1500-kw. generator at 26 000 volts has been ruptured in this way, which is a fairly severe test. For oil-type switches he uses a switch which can either be manipulated manually or mechanically or automatically as a time-limit overload switch. The latter arrangement is as follows: the switch is held in position by a tripping device. If the latter is tripped a spring will open the switch. That tripping can be done either manually or by means of a magnet. The magnet in its turn can be energized either by directly closing a switch in the circuit providing it with current, or by a relay, the latter being actuated by overload currents. These currents set up in the relay a magnetic field which tends to turn an aluminum disc and the turning of this disc winds up a weight. As soon as the weight comes to its top position it closes the relay circuit. If the overload is very heavy the disc will revolve very fast, and thus the switch will be quickly released. If the overload is light, it may happen that it ceases before the weight reaches the top position and it will then re-descend and the switch will not be tripped. This constitutes an absolute time element overload relay, and makes out of the switch an ideal automatic circuit-breaker.

[COMMUNICATED BY LETTER.]

H. F. PARSHALL:—Before the perfection of the oil-switch, the air-switch with long break and large clearance for flaming was the most reliable device and many of the early installations owe their success to the use of the air-switch. Subsequent experience gained is that oil-break switches can be installed in a great deal less space and can be depended upon to open the circuit with much less damage to the switches. The one condition which his experience would lead him to impose in connection with oil-switches is that there must be absolutely no inflammable material in the switch other than the oil; that is to say, the use of wood and such like materials for separators and insulators is to be avoided.

In a brief written communication, A. R. Henry described a switchboard of the Canadian Electric Light Company's powerhouse, Chaudiere Falls, Quebec.

DISCUSSION ON "TERMINALS AND BUSHINGS FOR TRANSFORMERS."

RALPH D. MERSHON:—In Mr. Moody's paper there is one point in regard to the terminals for high-pressure transformers with which the speaker thoroughly agrees. The speaker considers that the marble terminal board has no place in high-pressure transformers. The leads should be brought out to porcelain insulators located underneath the oil, each to its separate insulator. In a number of cases troubles have occurred on marble terminal boards, at times too difficult to remedy. A marble terminal board scored by a discharge and afterward apparently made perfectly clean by scrubbing, will not stand the normal pressure when again put into service, and the only way in which it can be made to stand is to chip out the marble where the discharge occurred. Instead of using rubber-covered cables in air-blast transformers for high-pressure terminals, as Mr. Moody suggests, the speaker prefers to have these terminals come out into the air and remain bare during the rest of their course to the sub-station or the next bank of transformers.

C. E. SKINNER:—Every transformer designer who has had to do with pressures of 20 000 volts or over appreciates the difficulty of bringing out the high-pressure terminals from such transformers. It not infrequently happens in extra high-pressure work that the size of the transformer, and particularly the containing case, is materially modified by the requirements for bringing out the terminals. In the case of air-blast transformers pressures are limited by the tap to an amount which makes the problem comparatively simple, provided a large number of ratios have not been required to increase the flexibility of the system.

In the case of oil-insulated transformers the pressures have already gone as high as 55 000 volts in actual service, and higher pressures are now being seriously considered. As stated by Mr. Moody in his introduction to the discussion on this subject, these higher pressures present a very formidable problem to the designer, and this difficulty is sometimes still farther increased by the requirements for the transformer case to be able to withstand considerable mechanical pressure. Mr. Moody has mentioned some common forms of bushings, which have been used for the purpose of insulating the main high-pressure terminals. Wooden tubes alone are not satisfactory for pressures, which at the present time may be considered as high. Hard-rubber tubes deteriorate rapidly. Glass and porcelain are mechanically fragile, and it seems next to impossible to get a moulded porcelain of sufficient dimensions for some of the higher pressure now being required.

As a general proposition it is necessary for the higher pressures that the distance between the high-pressure conductor and the metal of the case, where the conductor passes through, must be of such a value and the material of such quality that there will be no appreciation brush discharge at this point. Where

the transformer tanks are not required to withstand heavy pressures a satisfactory construction consists in fastening a slab of insulating material, such as marble, in the top of the cast-iron cover into which are placed heavy tubes for the conductors with sufficient extension to give the necessary surface insulation. Tubes made up from alternate layers of varnished paper and mica have proved very effective. In one instance where the line voltage was 50 000 the transformer case was required to withstand a pressure of approximately 100 pounds per square inch. In this instance the marble slab mentioned above was not allowable on account of the mechanical pressure requirements and the problem was solved by making extra heavy bushings, which passed through stuffing-boxes arranged to clamp the tube very tightly. This has given excellent service.

An interesting example of bushing trouble occurred on a 55 000-volt line where the bushing consisted of a glass tube with 0.625 in. wall incased in a heavy wooden bushing for mechanical protection, the combination being set in a wooden cover. The static discharge over the surface of the glass tube scored the tube to a depth of 0.0312 in. to 0.0625 in., making the surface rough and finally a breakdown occurred directly through the tube, shattering it into many pieces. This shows that glass has a time-factor at extra-high pressures.

Mr. Moody mentions the complication frequently imposed in the construction of the transformer itself by requiring combinations for various pressures and for a slight amount of regulation by bringing out taps from the high-pressure windings. From the designer's standpoint the speaker wishes to protest against this practice of requiring almost universal flexibility. After the transformers are in service the operating man considers that the paramount idea is continuity of service. Every extra lead and tap complicates the design and makes the construction more expensive and difficult. It is possible, of course, to secure great flexibility by such means, but the chances of trouble from those leads and taps which are not in service, and the possibility of making a wrong connection, greatly increase, and it is the speaker's experience that in many cases where such elaborate systems are required they are never used.

[COMMUNICATED BY LETTER.]

IRVING A. TAYLOR:—Instances have been noticed in air transformers where an uninsulated or lightly insulated tap is brought out through the external coil insulation and a lead soldered on and the joint insulated. This leaves a weak spot on the lead insulation just where it enters the coil insulation. Leads should be heavily insulated to a point well within the coil-jacket and should pass through the latter in a slanting rather than a straight direction, so as not to leave a vulnerable point in it at the point of entrance,

In some cases internal leads are brought up through the top

layers. This is a grave source of weakness as it gives a creeping surface through the inter-layer insulation. It also makes it necessary to wind the upper layers around it, and these are therefore liable to be crushed together. Taps from inner layers should always be brought out from the end of the layer, and in such a manner as not to cut the inter-layer insulation.

Where main terminals are located in the path of the air-blast, a great deal of surface dirt and consequently a long, creeping surface should be reckoned on. Terminal boards in air-blast transformers for this reason appear to be a source of danger, and where there are not many terminals it would seem best to use cables with heavy caps, the joints being made inside the case and above the fire-damper, if such is used. Fire-proof cables should be used in or near the air chamber.

Leads from oil transformers give a great deal of trouble by syphoning oil, and it is not at all easy to suggest a certain way of stopping it. Mr. Moody's remark that a solid section in the lead is necessary is correct; but it is difficult to insulate this section in practice so that the oil will not creep between the layers of insulation and on to the stranded cable. After a good deal of experimenting, the writer used a porcelain tube (filled with sulphur) over this solid section, and found it to be about the only successful method of stopping creepage. Bushings through the case should be extended well above the iron and the cable should be sealed in with non-solvent, insulating compound (sulphur may be used), so arranged as not to pocket any oil, but to drain it off. It is best not to have the braided covering of the lead extend inside the case as it is liable to carry oil out.

Where transformers are connected to outdoor leads they should have a solid section, well covered with water-proof material, in the external lead, as water will follow through a stranded cable for a long distance and in large quantities. This is a frequent source of burn-out in cable heads, etc.

All transformer cases should be grounded to prevent fire and make them safe to handle. Attention should be given to the fact that the ground wire should be heavy in proportion to the circuit protecting devices used. Thus, a No. 8 wire should not be used on transformers protected by 300-ampere fuses on the secondary side. The ground connection should be electrically sufficient and its resistance should be tested to determine this, a moderate pressure being used.

Where rubber-covered leads are used, the rubber should be heavy (not less than 0.25 in. wall per 10 000 volts) and of high quality, and fire-proof covering should also be employed. Extra flexible cable is usually preferable.

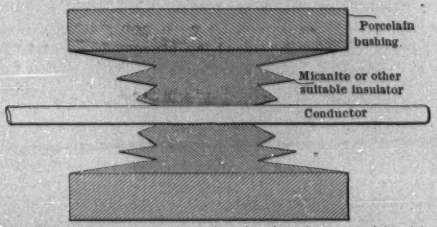
While taps allow one of the greatest advantages of the transformer to be utilized—that of obtaining different pressures from the same apparatus—it seems as though many specifications require more taps than are actually necessary. Taps cost money

on account of the necessary space, and besides are nearly always a source of weakness. They should therefore be avoided unless their use is absolutely justified. Except where transformers are to be used partly as pressure regulators, one 5% or 10% tap should give sufficient adjustment of ratio to meet lighting or railway conditions. Mr. Moody's remarks regarding the use of separate porcelain insulators instead of terminal boards are entirely correct. The writer thinks that the necessity of using a crane and taking a transformer apart to change or make internal connections, is hardly justified. Transformers should always be tested before connecting to their bank to discover wrong connections.

[COMMUNICATED BY LETTER.]

N. M. SNYDER:—The writer suggests that the design of the high-pressure insulator be drawn on—for meeting the conditions—without resorting to the oil-filled tubes for high-pressure terminals. First by making a suitable insulator for the glazed porcelain bushing, *e.g.*, to fit inside, having the conductor passing through its centre.

The insulator being double petticoated as the cut shows, gives a much greater resistance path than the straight bushing.



Side elevation cross-section showing insulator and bushing.

In bringing out heavy currents from transformers in multiple he concurs with the idea of sub-division of terminals, while it may introduce the necessity of more openings it has the advantage of distributing the load more evenly on the windings, assures less local heating and greater terminal surface for cooling.

[COMMUNICATED BY LETTER.]

A. C. PRATT:—In considering the location of internal terminals in transformers one point might well be brought to the attention of the designer of relatively high-pressure apparatus.

Many transformers for power transmission are provided for adjustment of pressure with taps on the high-pressure winding for cutting out perhaps 10% to 15% of the winding. These

adjustment taps are usually either in whole or in part located on the outer coils nearest the line terminals. If the line terminals be connected to a pair of these taps, cutting out say 5% on either end of the coils, then the maximum pressure to ground within the transformer becomes 10% more than from either line wire to ground. This material increase of insulation strains is especially undesirable in high-pressure transformers, where small brush discharges become troublesome, not only in air-cooled but also in oil-cooled transformers. Moreover the outer turns near these taps must be heavily insulated from one another to withstand lightning and other static strains.

If all these taps be made on adjacent ends of coils nearest the middle of the total winding, then the internal pressure in the transformer never exceeds line pressure; lightning strains are confined to the outer ends of the end coils, and when the taps are connected to cut out, say 10% of the total turns, the effect is merely an electrical over-lapping of the turns which are cut out, and the latter, if of equal number on the two adjacent coils, might even be connected in parallel, saving, in this assumed case, 7.5% of the $I^2 R$ loss in the high-pressure winding.

As to bushings, glass is being rightfully tabooed; it is fragile and necessarily of too small a diameter, thus naturally carrying too dense a charge on its surface, as noted in the paper. The tube is a condenser, the entire bore being at the pressure of the wire, and some other pressure, usually ground, applied near the middle of the outside of the tube. Charging current flows to and from the ground, along the tube, held close to the smooth surface of the glass, thus breaking down a thin film of air. The thinness of the film may be illustrated by wrapping strips of tape around the tube, when, upon applying test-pressure, the breakdown discharge will pass between the glass and the tape.

The remedy is, first, to increase the thickness of the tube wall thus decreasing the capacity (which is also affected by the kind of dielectric employed) and at the same time increasing the surface along which the charging current will flow, thus in two ways decreasing the current density on the surface of the bushing; secondly, further to break up and dissipate the surface-charging current by insulating rings set approximately at right angles to the axis of the bushing, as suggested in the paper.

It is essential that the wall of the tube be so made as to avoid long, thin air spaces extending along the axis of the tube, as these will be the seat of local currents, which may lead to the failure of the whole bushing.

MEETING AT PITTSBURG, APRIL 7, 1904.

Discussion on "The Relative Fire-Risks of Oil- and Air-Blast Transformers."

J. W. Farley:—For fires inside of transformers themselves, a chemical extinguisher can be used to good advantage. If a flash should occur inside the transformer, and ignite the oil which has soaked up on the insulation on the leads, the fire can be put out with ease by means of an extinguisher, which will be very effective even if the surface of the oil is actually burning.

Light brick walls may be built between the different transformers and low deflecting walls may also be arranged so that in the event of an accident to the transformer case, due perhaps to the falling of a beam or tile from the roof at the time of a fire, the escaping oil would be prevented from spreading over the premises and would be diverted either into a sewer or out of the building at some point where it would do the least damage. It is always a good plan to pipe from the transformer cases to a storage-tank or to a pit or sink-hole located in the most advantageous place, in order that in time of emergency the oil may be withdrawn from the transformers.

One field for the air-switch is its use for high pressures, where the amount of power is not very great. Under these conditions the air-switch will act just as satisfactorily as an oil-switch and often is very much cheaper than the latter. This is particularly true for pressures between 20 000 and 40 000 volts, and where the amount of power available on short circuit is comparatively small, as at the end of a transmission line at a sub-station with an output of 600 or 800-kw. Air-switches can easily be installed and at a cost probably not one half that of installing oil-switches.

Regarding the relative amount of space required by air-switches and oil-switches, in a complete layout for a typical transformer station for a single-phase railway plant it was found that the use of air-switches made just as compact, if not a more compact, plant than could be secured with the oil-switches, as the latter needed disconnecting switches and series transformers for their operation.

N. J. Neall:—The speaker has noticed that in the West so much more account is taken of the ability of electrical apparatus as to afford continuous service than of its efficiency. One instance of what is now considered an old station has the high-pressure transformers in the main power-house only a slight distance from the generator. During an accident to the switching apparatus considerable burning oil was thrown out on the floor of the power-house; this heated up the transformer cases but did not injure the transformers.

Another plant visited had placed each transformer in a complete building by itself, the idea being that if one transformer

went out it would not communicate fire to the adjacent transformers.

A. B. BOND:—There is one point in connection with air-break switches which has not been brought out to-night and that is the question of thoroughly drying out the switch before its installation. Conditions sometimes arise under which the wooden parts of the conventional fuse-switch may become damp and thus introduce an element of danger to the attendants.

In a prominent Western plant considerable trouble was experienced with fires in the oil-filled transformers. The cases were perforated at the top, and it was found that by thoroughly caulking up all openings, the trouble from fire was eliminated. In this plant it was customary to use sand for fires in transformers. A patent extinguisher was also employed in which the novel feature of an interrupted stream was incorporated. With this extinguisher it was impossible for an attendant to receive a serious shock in consequence of directing the stream on live high-pressure wiring—a danger that exists where a continuous stream is used.

MEETING AT PITTSBURG, APRIL 7, 1904.

DISCUSSION ON "THE USE OF GROUP-SWITCHES IN LARGE POWER-PLANTS."

B. P. ROWE:—It appears that the use or disuse of group-switches is one which will be mainly decided from the station operator's standpoint. The fact that the Metropolitan Street Railway Company in their 96th Street and Kingsbridge stations and the Manhattan Railway Company in its 74th Street station are both in favor of using group-switches seems to indicate that there must be enough good reasons for using the system to overbalance the objections Mr. Stillwell mentions, and any others he has not mentioned. The speaker has noticed that other large stations beside those of the Metropolitan and Manhattan companies are being laid out with group-switches, and for large stations of this class, with a large number of feeders, there seems to be a decided sentiment in favor of using this type of switch.

In the first place, if a power station is a large one no one questions the advisability of using two sets of bus-bars. If every feeder must be capable of being thrown to either of the two sets of bus-bars, there are required three oil-switches to each feeder. If the feeders are grouped as Mr. Stillwell has described, the two switches which act as selector-switches for one feeder will, if large enough, be suitable to transfer a whole group of feeders; so that with a double-throw system, the group-switches, acting as selector-switches, are rather a saving in apparatus than otherwise.

But when a single set of bus-bars is used, with the ring system

and junction-switches, the group-switch is undoubtedly an extra to be considered, just as Mr. Stillwell has considered it. Such a case as this is the Kingsbridge power-station, where the group-switches were installed by the Metropolitan Street Railway Company, who already had had the experience of operating the 96th Street station to guide them, and considered them necessary.

Under such conditions, an arrangement of feeders is made, so that the opening of a group circuit-breaker does not shut down an entire sub-station. Mr. Stillwell presents a diagram which indicates that if the operator suddenly opens a group-switch in an emergency, to cut out a bank of six feeders, he thereby shuts down an entire sub-station. The arrangement the writer has in mind is to have one or two feeders from a group carried to one sub-station and the balance distributed to other sub-stations, so that each sub-station draws its supply of current through two or more group-switches. Thus the liability of shutting down sub-stations is not so great. The writer understands that the Kingsbridge and 96th Street feeders are connected in this way.

A point not brought out by Mr. Stillwell is that when a group-breaker is installed it must have a capacity sufficient to carry all of the feeders in the group and to open the total load under the worst conditions. Now if the feeders in the group are carrying large amounts of energy it is manifestly a more difficult thing to open it all on one switch than to divide the load and open it instead on the several feeder switches. In some cases it means a large switch and the amount of energy to be handled introduces an element which can hardly be neglected. There is obviously more liability that the large switch will cause trouble than any one of the smaller ones. In such a case a station operator would probably rather consider the group-switch an emergency-switch than to be habitually breaking large amounts of current on it to save time in transferring feeders or cutting them out of circuit.

This would seem to indicate that where feeders are of very heavy capacity so as to require large group-switches, they might be a source of trouble rather than a benefit unless they are reliable. Reliability is demanded because the group-switches are connected directly to the bus-bars. In the Kingsbridge power-station the opening of the group-switch automatically opens all the feeder-switches connected to it. This insures that there shall be two breaks in the circuit and might help out the group-switch.

[COMMUNICATED AFTER ADJOURNMENT.]

DISCUSSING PAPERS BY SLICHTER, STEINMETZ, AND OTHERS RELATING TO ALTERNATING-CURRENT RAILWAY MOTORS.

DUGALD C. JACKSON:—The writer notices that Mr. Steinmetz attributes the modern form of repulsion motor to Professor Elihu Thomson, and others including Mr. Blanck (whose discussions are stimulated by the papers of Messrs. Slichter and Steinmetz) attribute its development to Mr. Steinmetz. It seems only proper to point out that neither of these designations is historically correct. The repulsion motor capable of producing continuous rotation which was created by Professor Elihu Thomson contained an armature with individual open coils. This armature was caused to rotate by the repulsion brought to bear upon the coil which at any instant chanced to be in the most effective position,—this particular coil being short-circuited when in that position. A characteristic feature of the Thomson structure lies in the fact that the coils approach the most effective position with open circuit. When a coil reaches the effective position, it is short-circuited by the brushes and produces torque, for the short period of the short-circuit only, as the coil recedes from its most effective position.

The device which has now come to be known by the name of repulsion motor (and which is referred to in the above-named papers) is distinctly different from this. The armature winding is a closed-coil winding and the whole of the armature winding may be traversed by the induced current at every instant. This device was invented by Anthony, Jackson, and Ryan, in 1887, and the earliest published description of such a motor with which the writer is acquainted is contained in the Anthony-Jackson-Ryan patent No. 389 352 which was issued on Sept. 11, 1888. Others are said to have independently invented the same device, including William Stanley and the late Charles J. Van Depoele in this country.

This type of motor has been constructed for a number of years by the Wagner Electric Mfg. Company,—which company uses the repulsion arrangement in the starting of their single-phase induction motors. Those who have had to do with these machines have long known that the repulsion motors have characteristics which afford excellent reasons for their introduction into electric railway service when the extension of electric railway lines produces a sufficient demand for an alternating-current railway motor. When used in such service it is desirable to introduce into their construction special means for reducing or abating the sparking at the commutator which is common to alternating-current motors constructed with a commutator.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Report of the Board of Directors for the Fiscal Year Ending April 30, 1904.

The Board of Directors presents herewith for the information of the Institute a report of its work during the past year, also of the financial standing of the organization.

The Annual Convention for 1903 was held at Niagara Falls, June 29–July 3 and was notable for the importance of the papers presented, the thorough discussion, and the attendance of nearly 500 members and guests, practically double that of 1902

The phenomenal growth in membership has continued, and the total has now passed 3000. The accessions continue by reason of the increasing appreciation of the work of the Institute, through the efforts of the Committee on Increase of Membership, supported by the co-operation of those already upon the roll in making known the advantages of being identified with the Institute. Through the establishment of Branches in many important cities, electrical engineers throughout the country have been brought into closer relations with the work of the Institute, and the Committee on Local Organizations points out the beneficial results of this practice. Most of the committees have presented reports of their year's work, and brief abstracts of these, show the general progress made.

Committee on Papers.—Seven meetings have been held for which arrangements have been made by this committee, although with two exceptions the number of papers has by request been limited to two in order to allow more time for discussion. Of the 17 papers, four were voluntarily submitted by the authors, while 13 were prepared at the request of the committee. Papers are more readily obtained when a specific subject is suggested, and the diverse interests of the personnel of the committee have facilitated more intelligent work in this direction. This has also led to the organization of the discussions which have been more spirited and valuable. The holding of Branch meetings has also led to the accumulation of additional material which in many cases is of great importance, due to the practical experience of members working under varied conditions in different parts of the country.

The Editing Committee.—The duties of this committee have been largely increased by the great increase of matter from Branch meetings. It has also brought about the printing of papers in the monthly editions

sufficiently in advance of meetings to enable members to prepare themselves to discuss them intelligently, and also permit those who are at a distance to send in contributions to discussions so that they may be read, or incorporated in the printed record.

Finances.—An important change in the care of funds has been made by this committee. As will be seen by the Financial Report, separate bank accounts have been established representing certain funds which are drawn upon only for the specified purpose of said funds. In order to carry out this plan it was necessary to convert into cash seven $1000 U. S. bonds held by the Institute from which $7,409.37 was realized. These funds as well as the current bank account of the Institute are now deposited with the Mercantile Trust Co., and Farmer's Loan and Trust Co., with the exception of $8000 in U. S. bonds which remain in a safe-deposit compartment of the Colonial Trust Co. The existing condition of the Institute's finances appears elsewhere in this report. The form of this statement having now been standardized it has become practicable to print opposite nearly every item, the corresponding figures of the previous year for the purpose of comparison. The Secretary has had this innovation in view for some years past, but was unable to introduce it until now, on account of certain changes in the form of the statement.

The ordinary receipts of the Institute during the year ending April 30th, 1904, were $40,986.78. This amount was made up of $32,724.12 from members, including entrance fees from Associates and transfer fees from Members; $1203 in students' dues, and $7,059.66 from advertising and miscellaneous sources. The ordinary operating expenses of the Institute were $36,394.20, leaving a balance of ordinary receipts over expenses of $4,592.58.

Owing to the fact that for the year ending April 30th, 1903, disbursements properly chargeable to the Carnegie Fund were paid out of ordinary current receipts to the amount of $1,312.20 the balance for that year should properly stand at $1,933.78 instead of $621.58. It should also be noted that the sum of $541.62 paid out of ordinary receipts for the year ending April 30, 1904, for the expenses of the Land, Building and Endowment Fund Committee, should properly be charged to that fund, making the true balance stand at $5,134.20 instead of $4,592.58. On the other hand the Life membership receipts for 1903 were $600, and for 1904 were $200, neither of which sums should appear in this column except as a matter of bookkeeping. The true relative difference in the balances of operating receipts and disbursements to April 30th for the years 1903 and 1904 respectively should be $1,333.78 instead of $621.58 and $4,934.20 instead of $4,592.58 as corrected by this explanation. Adding to $3,600.42, which is the difference between these balances, a gain in accounts receivable of $1,485.78 for the year ending April 30, 1904, makes the total net gain for 1904 over 1903 $5,086.20.

The bank balance available for current expenditures on April 30th, 1904, was $7,861.44. Adding this sum to $8,875.63, the market value of the United States bonds owned by the Institute makes a total of $16,737.07 in cash or its equivalent. Subtracting from this amount $4,400, as due to the Life Membership Fund, gives a net balance of $12,337.07 in cash or its equivalent immediately available for any ordinary or extraordinary expenditure of the Institute.

The accounts payable on April 30th, 1904, were $246.44 against which were accounts receivable amounting to $9,893.42, consisting almost entirely of arrears in dues, but not including any debts owed by members suspended or dropped for non-payment of annual dues. During the year the plant of the Institute was increased by the purchase of Transactions, library books and fixtures, and office furniture to the extent of $3,523.19 all of which was charged to current revenue.

The inventory valuation of the Library has been increased over the amount reported last year by $12,300.38 for the reason that statistics were not available at that time to show its actual value. It has since been appraised by a special committee and the amount of $21,737.13 accepted as satisfactory.

The Board of Examiners.—All applications for transfer from the grade of Associate to Member, for election as Associates, or for enrolment as Students, are considered by the Board of Examiners. Ten meetings have been held, and a grand total of 1042 applications have been reported to the Board of Directors as follows:

	Recommended.	Not recommended.
For Transfer	43	26
For Election as Associates	649	7
For Enrolment as Students	313	4

1st woman applicant was offered, but not accepted by Board of Directors

total elected 819

Committee on Increase of Membership.—The record of an increase of membership by the election of 798 Associates is a sufficient indication of the work of this committee in the past, but it is still engaged in its efforts to reach the very large number of eligible electrical engineers who will no doubt appreciate the benefits of membership when the matter is properly presented to them. It believes a systematic canvass may yet be made through the branch organizations which will be of great service to the Institute.

Local Organizations.—The Institute Branches have been increasing in number and in interest. There are at present, 29, of which 15 are in cities, and 14 are student meetings in technical schools. The average aggregate attendance at these meetings is 1250 (about 400 being students.) The Branch meetings are reaching our members and the young men who are to be the future electrical engineers of the country, in a way which enormously increases our activity and our influence.

The Report of the Committee on Local Organization, based upon reports from the branches, is appended to this report. It shows a remarkable development, a sustained interest, and encouraging prospects for the future.

International Electrical Congress.—While the actual organization of the Congress has been carried on independently of the Institute, there has been continued and harmonious co-operation, which it is believed will lead to the best possible results. The Institution of Electrical Engineers will be the official guest of the Institute, while all foreign delegates and members of various foreign electrical organizations will participate in the circular tour, arranged by the International Electrical Congress General Reception Committee and the Committee on Transportation and Arrangements. The itinerary as planned provides for brief technical visits on the way to St. Louis by the Northern route, including Boston, New York, Schenectady, Montreal, Niagara Falls and Chicago, also

Pittsburg, Washington and Philadelphia upon returning. The stay at St. Louis will cover the week of the Congress, September 12–17, during which the Institution of Electrical Engineers will hold a joint meeting with the Institute. The Congress subscribers now number about 1300, and 150 papers have been promised which are to be published in three volumes.

Cadmium Cell.—In accordance with a resolution adopted at the Niagara Falls Convention, a committee appointed to report upon the adoption of a standard cell has prepared specifications, and suggests that it be given the name "Weston Normal Cell." It is understood that this matter will be submitted to the International Electrical Congress, and that the cell will become a universally recognized standard.

Union Engineering Building.—This project which was brought before the Board of Directors and the Annual Meeting a year ago, has assumed a different form owing to the declination on the part of one of the national engineering societies to enter into it. This made it necessary to obtain from Mr. Carnegie his assent to a renewal of his offer to the other societies, which he did, increasing his gift by 50% as shown in the following letter:

GENTLEMEN OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AMERICAN INSTITUTE OF MINING ENGINEERS, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, AND THE ENGINEERS' CLUB OF NEW YORK:

"It will give me great pleasure to devote, say, one and a half million dollars for the erection of a suitable home for you all in New York City.

With best wishes,

Truly yours,

ANDREW CARNEGIE."

The land has been purchased in behalf of the societies, by Mr. Carnegie who has advanced $502,000 for the purpose, for which he is to be eventually reimbursed. The United Engineering Society, which is to hold the property, has been provided for under the laws of New York State, each of the three engineering societies named in Mr. Carnegie's letter being represented upon its board of trustees.

An architectural competition has been arranged in which six architectural firms have entered, and designs are to be submitted to the joint committee on June 20th, 1904. It is expected that the demolition of the buildings on the property will begin July 1st, 1904, and that this, and the construction of the new building will proceed continuously thereafter.

Building Fund Committee.—Four announcements have been issued by this committee, which reports that $41,000 has been pledged toward the amount of $200,000, the estimated requirement for the purchase of land, upon which Mr. Andrew Carnegie will erect the Union Engineering Building. The committee has received cordial and enthusiastic letters from Branches indicating that a strong regard for the Institute has been developed, which should encourage a liberal policy toward them on the part of the Institute as a whole.

Transmission Committee.—During the past year this committee arranged for papers and discussions at one day's session of the Convention at Niagara Falls, and a meeting in New York March 25. It is now making preparations for a special meeting at Chicago June 21 and 22, 1904, to be devoted exclusively to transmission subjects. A report of the committee at this meeting will embody the returns received from

the list of questions distributed last year. The success attained in gathering information in this field has led to a suggested plan by the chairman, that similar committees composed of engineers of experience, in the more important branches of electrical work, could by a systematic campaign take up the discussion of important problems at certain meetings of the Institute.

Engineering Data.—The chairman of this committee has made an earnest effort to gather information which could be utilized for the benefit of the membership. Nothing could be accomplished without co-operation, and having received practically no support, no progress has been made.

By-Laws.—During the past two years a committee has been engaged in framing by-laws, in order that the business and professional affairs of the Institute might be systematized. At the meeting of the Board of Directors, April 22, the by-laws reported by this committee were adopted, and are now in force. They have been printed in the April issue of the Transactions, and will subsequently be issued separately or in conjunction with the Constitution. If the membership will consult these by-laws the Secretary's office should be relieved of much correspondence, as many inquiries regarding the administration of Institute affairs will then be unnecessary.

Membership.—The total membership at the close of last year's report was 2,229, classified as follows:

Honorary Members	2
Members	417
Associates	1,810
Total May 1, 1903	2,229
Elected prior to May 1, 1903, and since qualified	177
Elected May 1, 1903, to April 30, 1904, and qualified	729
Restored to Membership	1
	3,136
Total Deaths	13
Total Resignations	12
Dropped as delinquents	84
	109
Grand total, April 30, 1904	3,027

The membership April 30, 1903, was classified as follows:

Honorary Members	2
Members	459
Associates	2,566
Total	3,027

The gain in membership during the year was 798, an increase of 35 per cent. As there are now applications pending and associates elected but not yet qualified to the number of 165, there is an immediate prospective total of about 3,300 members.

Associates Elected.—The Associates elected during the year, May 1, 1903, to April 30, 1904, and their present status is as follows:

Qualified and now Associates	729
Elections cancelled	1
Not qualified on April 30	89
Total elections	819

Resignations.—The following Members and Associates have resigned in good standing during the year:

Members.—Clayton C. Hall.

Associates.—W. J. Morrison, Jr., H. N. Ramsay, C. H. Thordarson, V. H. Yarnall, F. A. Cosby, T. H. Foote, F. J. Lamb, L. A. Lindsey, C. J. Marsh, J. C. Finney, Henry Schroeder.

Deaths.—There have been the following deaths during the year:

Members.—Frankland Jannus, T. E. Theberath.

Associates.—E. T. Gilliland, Benjamin Brown, J. J. Crawshaw, C. D. Crandall, W. O. Garrison, Francis Forbes, G. S. Johnson, J. L. Kebler, J. B. O'Hara, W. H. Simpson, F. E. Perry.

FINANCIAL STATEMENT FOR APRIL 30, 1904

ASSETS AND LIABILITIES.

ASSETS			LIABILITIES	
1903.		1904.	1903.	1904.
$2,006.75	Cash	$21,144.47	$787.93	General Library Fund $369.67
16,285.00	U. S. Bonds, market value	8,875.63	4,643.60	Carnegie Fund	4,432.38
9,436.75	Library Volumes and Pixtures	21,737.13	1,100.00	Land, Building and End. Fund	7,609.93
2,957.50	Transactions	4,624.50	4,200.00	Life Membership Fund	4,400.00
495.30	Office Furniture and Fittings	632.63		Mailloux Fund	1,000.30
154.50	Badges	138.00	10,556.68	Reserve Fund (Cash)	12,337.07
231.25	Congress Books	201.00	19,311.48	Surplus(Property etc.)	37,597.43
8,407.64	Accounts Receivable	9,893.42		
500.00	Sec'y's petty cash	500.00		
125.00	Type, etc			
$40,599.69		$67,746.78	$40,599.69	$67,746.78

RECEIPTS AND DISBURSEMENTS.

ORDINARY RECEIPTS.			ORDINARY DISBURSEMENTS.		
1903.		1904.	1903.		1904.
$3,305.00	Entrance Fees	$4,463.00	$697.00	Stenography & Type writing	$547.44
17,583.95	Current Dues	25,219.50		Stationery & Printing	3,058.36
1,168.47	Past Dues	1,523.12	2,148.15	Postage	1,947.52
740.59	Advance Dues	1,025.50	1,543.50	Express	813.83
◆ 800.00	Life Membership Fee	◆ 200.00	346.54	Badges	1,059.74
1,752.24	Transactions Sales	1,249.83	619.93	General Expenses	742.96
463.63	Transactions Subs.	543.40	867.95	Certificates	36.50
64.63	Binding	49.35	93.90	Office Furniture	359.72
1,685.51	Advertising	3,185.87	239.60	Salaries	6,027.88
23.67	Electros and Cuts	23.79	5,350.41	Cuts and Electros	1,909.67
783.50	Badges	1,164.50	1,778.93	Publishing Transactions	9,067.47
220.00	Transfer Fees	493.00	7,254.16	Rent	2,370.04
16.10	Congress Books	9.00	1,688.04	Advertising	232.50
496.36	Interest	544.13	804.88	Com's'ns	576.18
	Students' Dues	1,203.00	577.71	Binding Volumes	876.83
	Exchange	12.79		Binding Pamphlets	772.55
	Branch Meetings	77.00	1,208.43	Meeting Expenses	1,184.34
1,028.23	Library Donations		40.65	Branch Meetings	107.58
242.80	Library Volumes		154.27	Office Expenses	1,505.04
5.00	Meeting Refund		3,994.62	{ Library Rent	828.00
1.57	Postage			{ Library Salaries	393.21
				{ Library Miscel.	1,417.97
			330.00	Library Volumes & Fixtures	17.25
			21.00	Students' Expenses	
				Expenses Land, Bld. & Endowment Fd.	◆ 541.62
◆ 621.58				Balance	◆ 4,592.58
$30,181.25		$40,986.78	$30,181.25		$40,986.78

SPECIAL RECEIPTS AND DONATIONS AND SPECIAL EXPENDITURES

(Not Embraced in Above Statement.)

Special Receipts and Donations.	1904.
Land Building and Endowment Fund, Donations	$6,509.93
General Library Fund, Donations	208.05
Mailloux Fund, Donation	1,000.00
Mailloux Fund, Interest	29.50
Sale of U. S. Bonds	7,409.37
Total	$15,156.85

Special Expenditures.	1904.
General Library Fund, Expenditures	$53.37
Mailloux Special Fund	29.20
Carnegie Fund, Disbursements by Warrant	492.39
Carnegie Fund, Disbursements from Petty Cash	36.75
Balance	14,545.14
	$15,156.85

The total receipts for 1904, exclusive of donations, were in excess of 1903		$11,833.76
The total Disbursements for the year 1904 were in excess of 1903		6,834.53
Due from Members account of entrance fees and dues		9,281.78
Due on Miscellaneous accounts		611.64
Unpaid bills, May 1, 1904, amount to		246.44
Total Cash Receipts from ordinary sources	40,986.78	
Total Cash Disbursements, account ordinary expenses	36,394.20	
		$4,592.58 ◆
Property on hand according to inventory, May 1, 1904:		
Office Furniture and Fittings	$632.63	
Badges	138.00	
Transactions	4,624.50	
Congress Books	201.00	
Library, Volumes and Fixtures	21,737.13	
		$27,333.26

TOTAL NET ASSETS.

Cash:—		
Mercantile Trust Co., deposit	$7,861.44	
Farmers Loan & Trust Co., Gen'l Library Fund	369.67	
Farmers Loan & Trust Co., Building Fund	7,609.93	
Farmers Loan & Trust Co., Carnegie Fund	4,303.43	
Certificate of Deposit, Mailloux Fund	1,000.00	
	$21,144.47	
Secretary's Petty Cash	500.00	
U. S. Bonds, market value	8,875.63	
Inventory (as above)	27,333.26	
		$57,853.36
Total Net Assets last year		32,192.05
Increase		$25,661.31

PROPERTY PURCHASED DURING THE YEAR.

(Reported as directed by the Constitution.)

Office Furniture and Fixtures	$359.72
Library Fixtures	370.00
Library Books and Binding	1,047.97
Transactions	1,747.50
	$3,525.19

Respectfully submitted for the Board of Directors,

RALPH W. POPE,

Secretary.

◆ See explanation regarding comparative balances, third paragraph in text under head of Finances.

TREASURER'S REPORT.

FROM APRIL 30, 1903, TO MAY 1, 1904.

Dr.

Balance from May 1, 1903		$2,006.75
Received from Secretary, May 1, 1903, to May 1, 1904		
on account of General Fund		42,314.84
on account of Carnegie Fund		4,795.82
on account of Library Fund		423.04
on account of L. B. and Endowment Fund		7,609.93
on account of Mailloux Fund		1,000.00
		$58,150.38

Cr.

Disbursements on warrants from Secretary, Nos. 1833 to 2143, inclusive			
	against General Fund		$36,460.15
Warrants No. 1 to 14 Inclusive	against Carnegie Fund		492.39
	against Library Fund		53.37
Balances to New Acct.	General Fund	$7,861.44	
"	Carnegie Fund	4,303.43	
"	Library Fund	369.67	
"	L. B. & End. Fund	7,609.93	
"	Mailloux Fund	1,000.00	
			$21,144.47
			$58,150.38

Respectfully submitted,

GEORGE A. HAMILTON,

Treasurer.

REPORT OF COMMITTEE ON LOCAL ORGANIZATIONS.

To the Board of Directors of the American Institute of Electrical Engineers:

At its September meeting in 1902 the Board of Directors appointed a Committee on Local Organizations for promoting the organization of local meetings. The primary purpose of these meetings was stated to be the presentation of the papers and discussions of the regular meetings of the Institute and for the discussions of them, to be supplemented, however, by new papers, especially on subjects of local interest. The Committee was further given the general direction of a new line of work in connection with technical schools and universities by which local Institute meetings should be held among the students.

The present system of local meetings has been organized under the general auspices of the Committee; the local organizations, however, have been comparatively free to adopt such methods as seemed best. In the light of the experience thus gained the Board of Directors has recently adopted by-laws relating to the organizations and conduct of local meetings. Local meetings are now organized in 29 places which include many of our principal cities and technical schools. Branches are formed in each of the four cities ranking next to New York in population.

Statistics.

The accompanying statistics have been prepared from the monthly reports and other data in the Secretary's Office, checked in most cases by the local secretaries.

Several striking features in connection with the statistics are the following:

1. *Attendance.*—The monthly aggregate attendance at the Branch meetings is over 1300; the average attendance at the New York meetings does not exceed 200. It follows therefore that the number of men who come in personal contact with the Institute through Branch meetings is six times as great as through the New York meetings.

Discarding the meetings in technical schools the aggregate membership in 10 cities in which branch meetings are held is 888 and the aggregate average attendance at these meetings is 729. The attendance including visitors is 83% of this membership. The Institute membership within commuting distance of New York is 794 and the attendance at the New York meetings is, say 200, or 25% of this membership. It follows therefore that the attendance at the branches is proportionately greater than that at the general meetings in New York City.

STATISTICS OF BRANCHES, MAY, 1904.

Branches and Date Started.	Jun. 1 1902.	Membership Apr. 20 1904.	Increase	A.I.E.E. Students	Meetings Since Oct. 1902	Average Attendance.	Original Papers Since Oct. '02
1 Chicago..... 1903	76	152	76	39	12	115	6
2 Minnesota..... Apr. 7, '02	9	12	3	5	16	20	1
3 Pittsburg..... Oct. 13, '02	44	128	84	15	17	113	6
4 Cornell University. Oct. 15, '02	5	14	9	19	20	58	2
5 Lehigh University. Oct. 15, '02	3	4	1	1	15	35	3
6 Univ. of Wisconsin Oct. 15, '02	6	19	13	12	66	25	2
7 Univ. of Illinois... Nov. 25, '02	2	5	3	6	12	45	0
8 Denver..... Dec. 8, '02	6	32	26	—	6	40	4
9 Cincinnati..... Dec. 17, '02	15	47	32	2	8	55	3
10 Ohio State Univ.. Dec. 20, '02	2	2	0	13	17	28	1
11 Penna.StateCollege Dec. 20, '02	1	1	0	11	38	32	2
12 Univ. of Missouri.. Jan. 10, '03	1	1	0	5	12	22	0
13 St. Louis..... Jan. 14, '03	14	60	46	—	13	24	4
14 Purdue University. Jan. 26, '03	5	5	0	48	14	24	2
15 Schenectady..... Jan. 26, '03	49	113	64	17	11	110	3
16 Philadelphia..... Feb. 18, '03	55	92	37	1	13	98	6
17 Boston..... Feb. 13, '03	120	195	70	2	10	127	7
18 Iowa State College. Apr. 15, '03	1	5	4	21	14	58	8
19 Washington, D. C. Apr. 9, '03	28	44	16	1	10	58	13
20 Toronto..... Sept. 30, '03	4	24	20	4	7	15	2
21 Columbus..... Dec. 20, '03	4	33	29	1	8	14	1
22 Seattle..... Jan. 19, '04	11	17	6	—	3	15	—
23 Atlanta..... Jan. 19, '04	4	19	15	5	1	8	—
24 Armour Institute.. Feb. 26, '04	1	1	—	31	3	25	2
25 Washington Univ. Feb. 26, '04	1	1	—	6	1	5	—
26 Univ. of Michigan. Mar. 25, '04	3	3	0	17	1	25	—
27 Univ. of Arkansas. Mar. 25, '04	1	2	1	2	4	22	1
28 Worcester Polytechnic Institute. Mar. 25, '04	5	10	5	4	21	35	1
29 Pittsfield..... Mar. 25, '04	13	27	14	—	2	65	—
	494	1068	574	273	375	1316	80

Again, the total attendance at the New York meetings is equal to 6 per cent. of our membership while the total attendance at the New York and the Branch meetings is nearly 50% of our membership.

It may be noted that the attendance at branch meetings includes a much larger proportion of non-members than the New York meetings. This indicates a wider influence through the branch meetings than there is in New York. The room in which the New York meetings have been held has been too small to accommodate those who would be glad to

attend so that the invitations to outsiders have been restricted. This limitation may be removed when the new Engineering Building is completed.

2.—*Branches in Cities.*—The successful organization of branches in the larger and older cities which are already supplied with engineering societies and technical meetings is notable. Some of the strongest and best supported of the branches are in such cities. Electrical workers distributed through manufacturing and operating companies and other interests in these cities have not been brought together through engineering societies, nor has the INSTITUTE itself appealed to many of them. The INSTITUTE meeting has a distinct value from the engineering standpoint and the advantage of acquaintance and association, and has in fact opened a new field which has not been clearly recognized. Branches have been formed in fifteen cities.

3. *Student Meetings.*—The general interest taken in INSTITUTE meetings by students is significant. Professors of electrical engineering recognize the value to their students of the work of the INSTITUTE and a study of its papers reflecting as they do the present tendencies of electrical engineering and the latest achievement in electrical work. In some institutions electrical engineering societies which were languishing have taken on new life as in INSTITUTE branches. Meetings are held in fourteen institutions. The average attendance is over 400. This attendance of students does not include those who attend the Branch meetings in cities.

4. *Papers and Discussions.*—The Branch meetings are supplied with the papers presented at the New York meeting and the stenographer's report of the discussion upon them. The discussion at the Branch meeting is not infrequently by members who are better qualified to discuss the subjects in hand than those in attendance at New York. The Branches contribute materially to the value of our transactions, both by the discussion of papers and by the occasional presentation of new material.

BRANCH REPORTS.

As a basis for the preparation of this report a circular letter was sent to the officers of the several branches from which the following is an extract:

"In addition to statistics showing the number of branches, membership and the like, it is desired to indicate the ways in which the work done in branches and in Student meetings is contributing to the welfare of the INSTITUTE and of its members, both collectively and individually.

"The rapid development of local organizations during the past year and a half has been one of the most notable features of our INSTITUTE activity. What results are being accomplished? What changes are being effected in the scope and effectiveness of our work? Is the local meeting simply an affair of passing interest, based on the enthusiasm of the moment, or has it a substantial basis? What do the conditions which are found and the results already attained indicate as to the permanency and the ultimate scope and value of this work?

"It is desired to have from those intimately identified with the work

of the branches, statements or reports upon which a general report may be based which will give a fair estimate of the success of this movement to broaden and nationalize the active work of the INSTITUTE.

"I would be pleased to have a letter from you giving your observations and views. It is suggested that the branch work be considered from the following points of view: [The six headings are given later in connection with the reports]."

Replies were received from all but two or three of the branches. In many cases both Chairman and Secretary replied and in Boston and St. Louis the letter of inquiry was transmitted to several members and a number of independent views were obtained. In all reports have come from 45 members of 27 of the 29 local centers. The mere fact that so many men—most of them busy men—have taken this interest in the matter is significant.

The striking feature in the reports is the unanimity of sentiment. There are none that do not show satisfaction with the results in the past or confidence in the future. Some propose new methods, but none even suggest discontinuing their work.

It is no easy matter to bring into brief compass the contents of so many reports. A general summary will be given and extracts will be made from some of the letters, although much that is intrinsically worthy cannot be given in the space available.

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1. *The value of the Institute to its members as affected by Branch meetings.*

The replies are unanimous that the INSTITUTE is of much greater usefulness to its members. Following are some of the expressions:

"Until the establishment of the Branches the value of the INSTITUTE to its members outside of New York, was largely of a sentimental nature." (Sanville, Philadelphia.)

"Hence from the educational view point I would conclude that the benefits derived from the local meetings are equal, if not superior to those derived from the regular meetings. In addition to the educational factor, there is the social element which constitutes a feature no less valuable than the educational one just referred to." (Freeman, Chicago.)

"Branch meetings give members something tangible in return for their money. We get as much benefit from the INSTITUTE as those members who live near New York City." (Humphrey, St. Louis.)

"I find that our meetings have quickened my interest and forced me to go thoroughly into each paper." (Shaw, University of Missouri.)

"The advantages gained both by the members and the INSTITUTE fully justify maintaining and continuing the branches." (Ayer, Boston.)

"The Branch meetings increase the value of the INSTITUTE to members of the local branch at least 100%." (Damon, Chicago.)

"The Branch meetings have more than doubled the value of the INSTITUTE to the local members." (Lanphear, Iowa State College.)

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2. *The effect of Branch meetings on the attitude of members toward the Institute.*

The replies show that there is closer personal interest and wider activity.

" Members feel now that they have a direct personal interest in all that the INSTITUTE does." (Humphrey, St. Louis.)

" The Branch meetings are of value in giving a personal element that is altogether lacking when membership means only paying dues and receiving the printed transactions." (Langsdorf, Washington University.)

" Personally I am of the opinion that the organization of the Boston Branch has prevented the Boston members from losing interest in the INSTITUTE. At various times during the past five years I have made efforts to get friends of mine in Boston to join the INSTITUTE but have always been met with a very decided feeling that it was not worth while; that the INSTITUTE was operated as a New York Club and was of no possible interest to any one outside of that city. How much truth there has been in this I cannot say but the starting of the Branch last year revived interest very decidedly and I think it has been a wonderful success." (Edgar, Boston.)

" The Branch meetings in the western towns serve to bring the members in closer touch with the INSTITUTE for the reason that very few are ever able to attend the New York meetings or the conventions." (Shaad, University of Wisconsin.)

" The Branch makes it possible to give a large number of men actual work to do for the INSTITUTE, which always results in a feeling of closer relationship than the occasional attendance at a meeting in New York gives. We accomplish this in Philadelphia by forming special committees and distributing the Branch work as widely as possible." (Sanville, Philadelphia.)

" A number of members who formerly took comparatively little interest in the affairs of the INSTITUTE are taking an active interest in the Branch meetings." (Eglin, Philadelphia.)

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3. *The effect of Branch meetings upon the attitude of non-members, particularly young men, to the Institute.*

The general tenor of the replies is indicated by the following extracts from the reports received:

" The attitude of non-members particularly young men to the INSTITUTE has been shown by the large influx of such men to the ranks of the INSTITUTE." (Bogen, Cincinnati.)

" The standing of the INSTITUTE locally is considerably increased. This was seen in our meeting last year when Mr. Arnold read a paper on, ' The Transportation Facilities of Chicago,' and when we had several members of the City Council with us who entered into the discussion." (Swope, St. Louis.)

" I certainly would never have joined the INSTITUTE had not this Branch been formed." (Caldwell, Boston.)

" I am satisfied that practically all of the members that have joined since we started the Branch meetings, have done so as a result of their interest in these meetings." (Hewitt, Philadelphia.)

" The Branches have a tendency to bring into the INSTITUTE a larger number of men, who have no professional standing, than would otherwise have come in. These men, however, are frequently the men who are doing the actual, new engineering work for the various corporations and industries. They are therefore a valuable acquisition to the INSTITUTE." (Sanville, Philadelphia.)

" Fully two-thirds of the attendance at our local meetings has been young men who have not yet become members of the INSTITUTE. It is

hard to say how any better plan than that of local meetings could be adopted to educate future members to the possibilities of the INSTITUTE work." (Damon, Chicago.)

"The conditions with the Pittsburg Branch are somewhat unique in that it meets in the hall of the Electric Club and is affiliated with the Electric Club [composed of engineers and apprentices of the Westinghouse Electric & Mfg. Company] to the extent that all of its members are invited to participate in the meetings. This circumstance perhaps gives the local branch an unusual opportunity for interesting those who are very apt to take advantage of membership in the AMERICAN INSTITUTE, and probably accounts to some extent at least, for the rapid growth of local membership which has nearly tripled in less than two years." (Lincoln and Peck, Pittsburg.)

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4. *The value of Institute work to students.*

In some cities students attend the local branch meetings. (Student meetings in technical schools will be considered later.) In Chicago, St. Louis and Columbus meetings have been held both by the branch and by the Students in technical schools.

The relation of some of the Branches in cities to students is indicated by the following extracts:

"We not only have got a lot of new members, but what is still better we have interested all the electrical students of this section of the country in the INSTITUTE, so that the majority of them, I think, rather look forward to joining when they get out of college." (Edgar, Boston.)

"Branch meetings must be of especial benefit to younger members, and that these young men take a deep interest in the meetings, I can vouch for, as a number from these works attend every one of our meetings in Boston. There have also been enroled thirty-six young men in the grade of Student. I am not familiar with the work of the college branches, but the interest taken by the students—so-called—of the General Electric Company [Lynn Works] indicates that the general interest of these young men is more than superficial." (Fleming, Boston.)

"The local meetings have been of great help to those who have attended. Our senior electrical engineering students attend the meetings almost to a man." (Shepardson, University of Minnesota.)

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5. *Do the Branches aid the Institute in its fundamental purpose,—"in the advancement of the theory and practice of Electrical Engineering * * * and the maintenance of a high professional standing among its members."*

The general tenor of the reports is to the effect that the Branches conduce to the substantial advancement of Electrical Engineering. In other words, the meetings do more than simply impart information and contribute to agreeable friendships. A few of the expressions are as follows:

The substantial advancement of the INSTITUTE is effected through Branch meetings "(a) by greatly increasing the number who come under the influence of the INSTITUTE;

"(b) by bringing to a much larger audience the papers presented;

"(c) By making a much larger number acquainted with the work and personality of the greatest engineers of the country;

"(d) By bringing out material for papers that would not otherwise be presented." (Caldwell, Columbus.)

"The Toronto Branch has aided in the advancement of the theory and practice of electrical engineering by the discussion which takes place

and which soon indicates who have the highest attainments, and in consequence a professional pride is developed which would not pe present were it not for the meetings of the Branch of the INSTITUTE." (Kammerer, Toronto.)

" The Branch is undoubtedly aiding in the proper preparation of men for the profession, and as a result it must in a secondary way be tending toward the future advancement of the profession." (Jackson, Pennsylvania State College.)

" The bringing about, rather than ' the maintenance of a high professional standing among its members ' will naturally take place by bringing the young men into personal relation with the full members, providing always that the qualifications for entrance to the higher ranks are made high." (Bogen, Cincinnati.)

" It is believed that the influence of this Branch will be felt over a large part of the Southeastern States and will tend to place the ethics of the profession on a higher plane." (Shoen, Atlanta.)

6.—*Is there a sustained interest in Branch meetings?*

It was anticipated that many branches would spring up in which interest would wane when the initial enthusiasm had spent itself. Local meetings have organized in 30 places. There has been but one suspension, that being in connection with a minor college in which there was a change of professors. Of the 29 remaining, one is in a state of suspended animation (a number of the leaders have left the city), but the others seem to be in a healthy condition. It is gratifying to note in reviewing the reports, the practically universal assurance that there is a sustained interest and that the prospects for the future are encouraging. A number of the branches have been started recently so that there is little experience upon which to base conclusions. There is a suggestion in the reports from two of the larger cities, in which there appear to be strong local engineering societies, namely Chicago and St. Louis, to the effect that it may not be best to hold meetings as frequently as once a month. A few of the reports, principally from the older branches are as follows:

" There is certainly a sustained interest in the branch." (Burch Minneapolis.)

" There is a pronounced interest in our local branch. The prospects for the future are very bright. We have a constantly growing membership among a good class of men." (MacKeen, Toronto.)

" The interest in the branch meetings has increased since its organization and the future prospects are bright." (Eglin, Philadelphia.)

" With regard to the St. Louis Branch I fear that it will be difficult to maintain interest under present conditions. Two meetings per month of the Engineers' Club, with one of the INSTITUTE, is too much of a drain on one's time for regular attendance at all of them. We should, I think push the matter of arranging a compromise system with the Engineers' Club, as outlined over a year ago." (Langsdorf, St. Louis. Layman expresses a like view.)

" There continues to be much interest in the Boston Branch and its prospects for the future are good." (Kennelly, Boston.)

" There is every indication that we shall not only maintain this interest, but increase the membership in this locality." (Bogne, Cincinnati.)

"We are glad to say that the interest in the meetings is well sustained and the prospects for the future are bright. In order to keep up a general interest we have had to introduce new subjects and we feel that our proceedings in this respect is accountable for the sustained interest in the meetings." (Betts, Washington, D. C.)

"I think we can safely say there is a substantial interest in the Chicago Branch and I further believe that its prospects for the future are very good." (Junkersfield, Chicago.)

STUDENT MEETINGS.

The introduction of INSTITUTE meetings in technical schools has brought results which are remarkable and significant. The instructors have taken up the matter with much interest and the students have taken hold in a substantial and enthusiastic way.

The manner of organizing and of conducting the meetings differs in different institutions. At one extreme the study of the INSTITUTE papers is taken up in a Seminary method under the direction of the professor as a part of the regular course. Weekly meetings are held and credit is given. On the other hand, an electrical engineering society among the students has merged into an INSTITUTE meeting with suitable by-laws and officers. Between these extremes various methods are pursued as may be best adapted to the local conditions. In general, however, the methods are the same in that the current INSTITUTE papers with their discussions are presented by students to whom they have been assigned. The subjects are then open for further comment and discussion. Current papers are often supplemented by past papers; the transactions of the INSTITUTE being in fact one of the best libraries of electrical engineering information.

The reports from the Student meetings are practically unanimous in showing active interest and substantial results. It is impracticable to give in full the reports received. The few extracts which are given, however, will serve to cover the ground and several are given rather fully to indicate typical methods by which the work is conducted.

"My opinion of the value of the INSTITUTE work has grown steadily as I have had a chance to observe its effects on students and graduates. They have grown under it and take a larger, broader view of the profession. They take pride in it. It calls for the exercise of sound judgment, and, as it were, stretches their minds to consider the larger problems of strictly engineering character. They are unanimous in their appreciation of the privileges they enjoy.

"Prospects for the future are bright. I expect to have a meeting a week during the next school year." (Shaw, University of Missouri.)

"A certain number of the senior class, together with the graduate students in Electrical Engineering, elect our course known as a Graduate Conference or Seminary and such students are invited to become affiliated with the INSTITUTE as Student Members or to join as associates, though this is not made a requirement of the course.

"Meetings of this Seminary are held weekly and different subjects are taken up and discussed, such subjects being furnished largely by papers presented at previous meetings of the INSTITUTE. A list of other references is prepared by the student who is to abstract the paper and the references. A written discussion to serve as the opening of a general discussion is required from a different student.

"One meeting of each month serves as the regular meeting of the Madison Branch. These monthly sessions are held at private houses mostly, and are open to any person who may be interested. These meet-

ings have been very successful this year. They are very informal, much in the nature of a "smoker," and have been well attended." (Shaad, University of Wisconsin.)

"I believe that a very decided reaction upon the work in the Department is felt in that in certain directions a practical turn is given to our Instruction work and in this way the local branch meetings are aiding in the advancement of the theory and practice of Electrical Engineering. The interest in the local Branch is sustained and increasing. We have recently sent in over thirty applications for Student membership and some additional applications for Associate membership, in the parent society." (Spinney, Iowa State College.)

"Four men who became Associates while here have left Ames which accounts for their not appearing in the list of local membership. During the past month four other men have made application. These applications are a direct result of the influence of the local branch." (Lanphear, Iowa State College.)

"This Branch consists of some thirty-one student members who are actively interested in the work of their branch, and at the same time are frequent visitors to the Chicago Branch meetings, as well as the local branch of the Western Society of this city. These young men discuss papers of their own that are the result of their experiences in the class room and the laboratory, as well as those of the INSTITUTE that come within their range." (Freeman, Armour Inst. of Technology.)

"The local branch is causing our students to become thoroughly acquainted with the INSTITUTE and to hold its aims and objects in high regard. This attitude is not confined merely to the local student membership but is true of the entire two hundred odd students pursuing Electrical Engineering." (Jackson, Pennsylvania State College.)

"During the past ten years there has existed among our students a vigorous organization known as the Cornell Electrical Society. This Society holds usually about 15 meetings a year for the purpose of hearing lectures or engaging in discussions. * * * This is one great reason why we have in the past held most of our branch meetings at an hour that would otherwise be given up to regularly required work for our seniors in Electrical Engineering. Another reason for doing this is that we want to require that every one of our electrical engineering graduates shall possess knowledge of the INSTITUTE, the benefits to be derived therefrom to have a start in the study and understanding of the transactions, and finally to know something of the men who have been or who are now prominent in its management or in the contribution to its transactions. We have remodeled the schedule of our senior courses somewhat for the express purpose of devoting one hour of required work per week to the INSTITUTE and its transactions." (Ryan, Cornell.)

"The work of the organization at this place has exceeded my expectations.

"The weakness of the isolated student organization which existed before the Branch was installed, was that it relied almost wholly upon local talent for the papers; the students themselves taking little or no part in the discussion of the same. Most of the work devolved upon the members of the engineering faculty.

"It has been our policy to leave the work of the Branch largely in the hands of the students, we, acting only in an advisory capacity and the results have been very gratifying.

"The increased number of calls for the transactions of the INSTITUTE in our library shows that the students have learned to appreciate the proceedings of the INSTITUTE as a source of reliable information". (Esterline, Purdue.)

"The students learn to know the leaders in INSTITUTE discussions, learn what are vital topics, and in general to believe that electrical engineering is something more than a matter of text-book knowledge. The

students appreciate the opportunity, and many have told me they would join as soon as able to pay the fees. The western state university is filled with a lot of eager but impecunious students, who are often actually unable to pay $3 for student membership, on account of class assessments especially in their senior year.

"At the moment judging from our experience I should say that the INSTITUTE is giving more than it is receiving, doing a glorious work. If the Branch privileges were removed I am sure we would feel the loss severely.

"The interest is sustained. We would like to get more advance papers, owing to our increased attendance, but I am ashamed to ask for them, unless the INSTITUTE makes arrangements to have at least the postage refunded." (Brooks, University of Illinois.)

"After the organization of the St. Louis Branch I encouraged my students to enroll as Student Members and to attend the regular monthly meetings. The response, however, was not encouraging, and inquiry developed the fact that the discussions were often too far in advance of the instruction (at the time of the meeting) to be intelligible to the students. For this reason it was decided to form an independent branch, so that discussions might be more free; incidentally, this permitted the reading and discussion of earlier INSTITUTE papers bearing on the subject studied in the class-room, in case the current ones should be ahead of the schedule of studies." (Langsdorf, Washington University.)

"Our first meeting was attended by some 65 students and visitors. Our branch is, I believe, a permanent organization in the University." (Gladson, University of Arkansas.)

"The prospects for next year seem very promising, the men being interested in the work of the branch, and anxious to see it succeed." (Sargent, Worcester Polytechnic Institute.)

BY-LAWS.

The By-Laws which have been recently adopted by the Board of Directors regarding branches formulate the general policy under which branches have been conducted during the past year and a half. There is a definite general relationship with the INSTITUTE and the important matters pertaining to the branch are subject to the approval of the Board of Directors. The branch, however, is allowed a wide latitude in the adoption of its methods and its rules and regulations. Conditions vary in different places and the branch is permitted to adopt methods which are best suited to the local requirements.

In the By-Laws a distinction is drawn between Branches (which require at least ten Members or Associates) and Student meetings. The Student meeting is responsible to the INSTITUTE through one of the members of the INSTITUTE who is a professor in the technical school. He is at liberty to follow such plans as may be found best. In those institutions in which there are ten or more Students of the INSTITUTE the Student meetings may be termed Branches. The organization, however, is virtually a meeting held under the direction of the professor in so far as official relations with the INSTITUTE are concerned, unless there be ten Members or Associates, in which case a Branch may be formed.

The privileges and the status of Students of the INSTITUTE are set forth in the By-Laws and it is expected that there will be a material increase in the number of Students during the coming year.

AFFILIATION WITH LOCAL SOCIETIES.

In several instances it has been found convenient or expedient to have the branch work in close relations with a local engineers' club or engineer-

ing society. Relations of this kind have been fostered. It has been the general policy to minimize the organization and management of the branch and to have it primarily devoted to meetings for the reading and discussion of papers. A preferred arrangement is that in which a local society will extend the use of its assembly hall for the INSTITUTE meeting, there being a general privilege and invitation to the members of the local society to attend and take part in the meetings. In this manner the benefit has been mutual. The INSTITUTE meeting may be regarded in one sense as a section meeting of the local society. On the other hand, the branch preserves its identity and there is no interference with the individualities of the two organizations.

GENERAL CONCLUSIONS.

The new place in modern affairs which has been taken by engineering, the great developments which have come through the application of electricity, the growth of the A. I. E. E. from its organization 20 years ago this month to the position which it now holds; the development of a new profession, the importance of the responsibilities devolving upon it—all open a new field for national engineering societies and for our INSTITUTE. The field and the requirements in engineering are different from those of 25 years ago. The field and the requirements in our own INSTITUTE are different from those of ten or even five years ago.

In most professions a man who was a competent engineer ten years ago might take up work now even though he had been out of touch with his profession in the meantime, but an electrical engineer who has not kept abreast of the changes in the past ten years would be quite out of date. The majority of the men in the profession are young men and hundreds of others are coming from the technical schools each year.

"It is the function of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS to bring individual workers into a common unity, to join them in a community of interest—a fraternity which is called the electrical engineering profession.

"It is the function of the INSTITUTE to bring together continually the diversified achievements of many workers which taken altogether constitute a single total of accomplishments—a total which is called progress." (President's address, October, 1902.)

In meeting these new demands and fulfilling the new conditions there must be a broadening of our activities. One of the most effective ways of nationalizing our INSTITUTE and of increasing its effectiveness is through the local organization. The Electrical Engineering profession therefore presents to our INSTITUTE a field for Branch meetings which is unique, and which is quite different from that possessed by our sister societies. We are confronted by new conditions; we must devise new methods. The results so far achieved and the indications now presented justify the belief that the formation of our branches is not merely a matter of present enthusiasm but that a new department of our work is begun which promises to be permanent and far-reaching in its influence.

For the Committee on Local Organization,

CHAS. F. SCOTT,
Chairman.

REPORT OF COMMITTEE ON THE CADMIUM CELL.

To the Board of Directors of the American Institute of Electrical Engineers:

The committee appointed by you to report on the preparation of materials and the construction of the cadmium or Weston cell has made very substantial progress, and begs leave to make the following preliminary report, with the request that the Committee be continued.

The most serious variations in the electromotive force of both Clark and Weston standard cells have been traced to the influence of the mercurous sulphate. (See Zeitschrift für Instrumentenkunde, February, 1901, and the Report of the National Physical Laboratory of England, for 1903.) The problem of ascertaining the cause of these variations and the development of a standard method of preparing the mercurous sulphate was accordingly taken up by the Chairman of this Committee in conjunction with Dr. George A. Hulett of the department of chemistry in the University of Michigan.

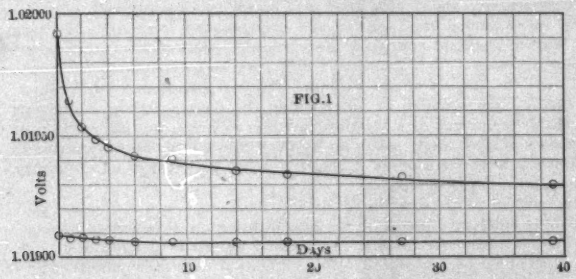
The method of preparation in use by the European manufacturers of mercurous sulphate consists in its precipitation by bringing together a solution of mercurous nitrate and sodium sulphate or sulphuric acid. This method has been repeated with a number of variations; and the various preparations give variable results when used in the cadmium cell, and all of them higher electromotive force than the mercurous sulphate prepared electrolytically, as described below. These results suggest that perhaps mercurous sulphate might carry isomorphously a small quantity of mercurous nitrate, since both of these salts crystallize in the monoclinic system. In fact Dr. Hulett has detected the nitrate in commercial preparations and in some of those made by himself. A cell set up with mercurous sulphate of the standard preparation, to which a trace of mercurous nitrate had been added, showed an increased electromotive force due to the nitrate. Not only does the presence of the nitrate raise the electromotive force of the cell, but the relative amount of the nitrate present appears not to be invariable.

In view of these facts, a new and standard method of making mercurous sulphate from pure mercury and dilute sulphuric acid appeared to be highly desirable. Such a method has been devised by Dr. Hulett; also independently by Dr. Wolff of the Bureau of Standards. (See paper by Henry S. Carhart and George A. Hulett in the Transactions of the American Electrochemical Society, Vol. V; also one by F. A. Wolff, same volume.)

A new electrolytic method of preparing the cadmium amalgam, and one for washing the mercurous sulphate to remove the acid without the use of pure water were also devised. (See specifications below.) The results are highly satisfactory, and cells made in accordance with the specifications appended to this report show remarkable agreement and constancy. Your Committee is well satisfied that the principal difficulties in making Weston cells have now been removed.

The two curves in Fig. 1 show the behavior of two cells for forty days after they were placed in a constant temperature bath, at 21.1° cent. Cell *D*6 was made with mercurous sulphate prepared in the old way by precipitation; cell *D*1 was made with the same materials, except that the electrolytic mercurous sulphate was used. Comment is unnecessary. The electromotive forces given are relative and not absolute.

The table exhibits measurements made on cells *D*1 to *D*4, and *F*1 to *F*10 all of them set up with the electrolytic mercurous sulphate. The figures were obtained by comparison with an old cell, *B*7, by means of a Wolff's potentiometer and a type *H* d'Arsonval galvanometer made by Leeds &



Northrup. The fifth decimal place could be read with the greatest ease.

In determining the effect produced by changing a single feature in the preparation of the materials, about 100 cells of the *H*-form have been made and tested. These are still under observation. All of them, except the first ten, have been hermetically sealed. The sealing is readily effected by making the glass containing cell of a special form, and sealing with two blast lamps.

The Committee offers the following Specifications, which are to be considered as provisional only, for the preparation of the cadmium cell with saturated solution and excess of crystals of cadmium sulphate. For the cell so prepared the Committee would suggest the name, "Weston Normal Cell."

1. MERCURY.

Mercury free from grease should be first shaken with a nitric acid solution of mercurous nitrate;* and, after drying, it should be distilled in a vacuum at least twice.

*Zeit. Ph. Ch., 33, 611.

Date.	D CELLS.				Date.	F CELLS.									
	1	2	3	4		1	2	3	4	5	6	7	8	9	10
Jan. 5, 21.0°	1.01909	1.01910	1.01910	1.01910	Feb. 15, 21.1°	1.01907	1.01907	1.01907	1.01908	1.01908	1.019065	1.01907	1.01908	1.01905	1.01907
6, 21.1°	08	09	09	09	16, 21.1°	065	06	07	08	07	06	06	07	07	065
7, 21.1°	08	08	085	09	17, 21.1°	07	07	07	07+	07	06	075	075	07	07
9, 21.1°	07	08	08	08	20, 21.1°	07	07+	075	08	08	08	075	07	08	075
11, 21.1°	07+	07	07	08	22, 21.2°	075	08	08	08	08	08	08	08—	08+	08
14, 21.1°	07	06	07	075	25, 21.0°	08	08	08	08	085	085	08	08	09	08
19, 21.1°	06	065	07	07+	Mar. 1, 21.1°	08	08	08	08+	08	08	08	08	08+	08
23, 21.1°	06	06	07	07	4, 21.2°	08	08+	08+	08+	08	08	08	08	08	08—
Feb. 1, 21.1°	065	065	07	075	12, 21.0°	075	08	08	08+	08	08	08	075	08	08
13, 21.1°	07	08	08	085	15, 21.1°	08	085	09	09	08+	08	08	085	085	09
16, 21.1°	07	08	08	08	17, 21.3°	075	08	08	08	08	08	08	08	08	08
18, 21.1°	07	07	08	08+	21, 21.3°	07	07+	08	075	07+	07	07+	07+	08—	08
22, 21.2°	07	08+	09	09	23, 21.3°	07	075	08—	075	07	07—	07	075	08—	
25, 21.2°	07	08+	085	09	28, 21.0°	075	08	08	085	08	075	075	08	08	
Mar. 1, 21.1°	07	07	075	08	Apr. 2, 21.2°	07	07+	08	08	08	075	08	08	08+	
5, 21.2°	07	07	075	08	5, 21.1°	075	08	08	08	08	075	08	08	08	
12, 21.1°	07	07	07	07+	9, 21.0°	08	08	085	08	09	08	08+	08	08+	
15, 21.1°	07	07+	07	075	16, 21.0°	08	085	085	08+	085	07	08	08	085	
17, 21.0°	06	065	07	07+	28, 21.1°	07	075	08	08	08+	08	08	08	08	

2. Cadmium Sulphate Solution.

The best pure commercial salt is dissolved at room temperature in its own weight of distilled water, with the aid of a motor-driven stirrer. The solution must be filtered until perfectly clear; it may then be placed in a large crystallizing dish in a small room, free of dust; it is of advantage to remove the water vapor by appropriate drying agents. The slow ensuing crystallization should yield perfectly transparent crystals. After about two-thirds of the water has evaporated, the mother liquor is poured off and *only the clear crystals are taken;* those that are white are redissolved and added to the mother liquor. The whole is then filtered and left to crystallize again. *The selected clear crystals are rinsed with distilled water, drained, and left to dry.*

To make a solution of cadmium sulphate for setting up cells, the pure crystals are put into an Erlenmeyer flask and covered with two-thirds their weight of distilled water. A suitable stirrer (Schultz stirrer, Ber. d. d. Chem. Ges., 1896, 2883) is driven by a motor, for the purpose of causing the water to circulate over the crystals, for at least half a day, preferably in a bath at 25° cent., controlled by a thermostat. The supernatant liquid should be clear and should remain so indefinitely. It should be left standing over the crystals, and when it is used it should be saturated at a temperature as high as 25° cent. The saturation of the solution is of great importance in order that the cells may quickly reach electrical equilibrium.

3. Cadmium Amalgam.

To prepare a 12.5 per cent. cadmium amalgam, free from zinc, a large crystallizing dish is nearly filled with a saturated solution of cadmium sulphate slightly acidulated with sulphuric acid. In a small, low crystallizing dish is placed a weighed quantity of pure mercury, and the whole is immersed in the cadmium sulphate solution. The pure cadmium of commerce is melted down into a large button with a stick of cadmium attached for electrical connection; or, several of the cadmium rods, bound together, are placed in a vertical position with their lower ends in the solution and beneath them a small, low crystallizing dish. If the cadmium disk or button is used, it is placed in the second low crystallizing dish, which retains the finely divided dross or powder. The metallic cadmium is then made the anode and the mercury the cathode, connection with the latter being made by means of a platinum wire sealed, except at its end, in a glass tube. The fall of potential from the anode to the cathode should not exceed 0.3 volt. An ammeter should be used to keep account of the quantity of electricity flowing through the cell, until something more than the necessary weight of cadmium has been deposited on the mercury cathode. The small crystallizing dish, containing the cadmium amalgam and some of the solution, is then removed and warmed over a bath till the amalgam melts under the cadmium sulphate solution. When cool it forms a crystalline disk. This method yields an amalgam free from zinc, and there is no oxide or dross formed, as there is when the amalgam is made by the method of heating. The solid amalgam should next be washed, dried on filter paper, and weighed. The necessary weight of mercury to make a 12.5 per cent. amalgam is finally added. The amalgam should be kept under a pure cadmium sulphate solution, and it

must be melted on a water bath to insure homogeneity before it is used in making a cell.

4. Mercurous Sulphate.

In a flat-bottomed glass vessel or deep crystallizing dish place pure redistilled mercury two centimetres or more deep. Cover with dilute sulphuric acid (one of acid to six of water) to a depth of 8 or 10 cm. Make electrical connection with the mercury as the *anode* by means of a platinum wire covered, except at its end, by a glass tube. For a cathode use a piece of sheet platinum so as to expose to the acid solution a surface of about 50 sq. cm. A current density of 0.5 ampere per 100 sq. cm. surface of mercury may be used. A crystalline mercurous sulphate forms soon after the current begins to flow from the mercury to the acid solution. A stirrer, consisting of a glass rod bent at right angles at the bottom, must be used to keep the mercury surface exposed. The foot of the stirrer must pass close to the mercury, and the stirrer must be driven rapidly by a motor to keep the mercury agitated.

A little over four grammes an hour can be prepared in this way with a current of half an ampere. The mercurous sulphate formed should be protected from the light, since mercurous sulphate darkened by exposure to light gives too high an electromotive force. The sulphate will be white or gray, according to the amount of finely divided mercury mixed with it. The presence of this mercury in a state of fine division is a distinct advantage. If the stirring is continued after the circuit is broken, the crystals of mercurous sulphate grow in size, become whiter, and subsequent treatment is easier.

The mercurous sulphate may be removed from the mercury by a separatory funnel. It should be kept under the acid solution, one to six, in contact with mercury and in the dark.

5. The Paste.

When ready to fill a cell, the mercurous sulphate, which has been kept in contact with mercury under dilute sulphuric acid, is brought into a Gooch crucible of about 25 c.c. capacity (about three-fourths), avoiding much free mercury, which interferes with the filtering. A tiny filter paper covers the perforations in the bottom of the crucible, and the whole is mounted on a Bunsen filter flask and attached to a filter pump.

The mercurous sulphate is first washed a couple of times with dilute sulphuric acid (15 c.c. concentrated acid to a litre of water), and then with the saturated cadmium sulphate solution. The washing with the cadmium sulphate solution should be repeated five or six times to remove all the acid; only a few c.c. of the solution are needed for a single washing; after each washing the cadmium sulphate solution is to be removed as completely as possible by the filter pump. The last washing leaves the salt ready to be made into a paste. The top layer after the last washing should be verified.

The paste is then made in a clean agate mortar by grinding together crystals of the pure cadmium sulphate and a little mercury, and then mixing in about three volumes of the mercurous sulphate; finally add enough saturated cadmium sulphate solution to make a thin paste.

6. Construction of the Cell.

The *H*-form of cell is the most convenient to fill. Fig. 2 shows the glass cell half actual size, ready to be filled. The tubing is drawn out

and contracted at *a* so as to leave the diameter about 6 cm. and with thin walls at this point. The amalgam is melted over a water bath and is introduced by means of a small tube, slightly contracted at the end, and of a diameter that will allow it to pass freely through the neck *a*. The warmed tube is used as a pipette, and permits the rapid introduction of the amalgam without splashing. It should always be wiped with a filter paper or clean cloth before it is introduced into the cell.

The mercury, the thin paste, and the concentrated cadmium sulphate solution may be introduced in the same manner. An alternative method is to fill the cell through little funnels, made out of small test tubes. They must pass through the neck at *a*, and reach well down toward the bottom. After the mercury and the paste have been introduced, both legs of the cell are filled with clean, dry crystals of cadmium sulphate. Enough of the saturated cadmium sulphate solution is finally added to fill the cell to the top of the cross connecting tube.

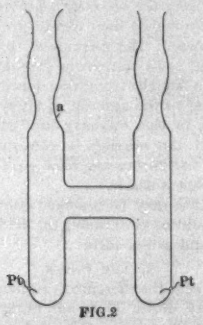


FIG. 2

The sealing off is readily done by means of two small horizontal blast flames, 5 cm. long, directed in a line toward each other and just meeting. The narrow part at *a* is brought between the impinging flames, the glass quickly softens, and the top part is drawn off. A cell sealed in this way contains nothing but the necessary materials of the voltaic combination. It can not leak, and can be immersed in a kerosene bath without danger that the oil will penetrate into the inside, as it does with sealing wax and paraffin.

After soldering copper wires to the platinum terminals of the cell, it is desirable to tie them securely with thread to the legs of the cell, as a precaution to avoid the breaking off of the platinum wire at the point where it enters the glass.

The Committee is indebted to Dr. Hulett for many suggestions in the preparation of these Specifications.

HENRY S. CARHART, Chairman,
EDWARD B. ROSA,
CLAYTON H. SHARP,
GEORGE A. HAMILTON,
} Committee.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

REPORT OF LIBRARY COMMITTEE.

We beg to submit herewith a report of the present state of the Library of the INSTITUTE, and the state of the several funds under the cognizance of this Committee.

During the past year no accessions by gift to the funds of the Library have been received, and a much smaller number of books have been added to the Library through donations than in the previous two years. This does not, however, signify any decrease of interest in the Library on the part of members, but follows from the fact that in view of the great sum of money to be raised by the INSTITUTE to fulfil the obligations assumed in connection with the Union Engineering Building, your Committee has refrained during the year from pressing upon the membership the claims of the Library to their support.

During the past year about $1000 was expended in the purchase of books in the English, German and French languages, the several lists prepared for this purpose having been carefully compiled to include the titles of the more authoritative works published during the past twenty years. The preparation of further lists of modern books required to meet ordinary needs has been deferred until some definite conclusions shall have been arrived at concerning the scope and organization of the proposed library for which quarters are to be provided in the Union Engineering Building, and of which the INSTITUTE collection will probably form part.

A catalogue of the periodical publications in the Library, including the Transactions of professional and scientific bodies, has been prepared and is now in press. In this the entries of

the periodicals which the Library does not possess in complete state will be followed by a note pointing out the portions lacking; and as a copy of the catalogue will be sent to each member of the INSTITUTE, it is hoped that this indication will lead to members giving their aid in filling out incomplete sets.

The Library has received from the C. & C. Electric Company, the Crocker-Wheeler Company, the General Electric Company, the Stanley Electric Mfg. Company, and the Westinghouse Electric & Mfg. Company, sets as complete as could be made at the present day, of the trade and engineering publications issued by these several companies It is hoped that similar collections may be obtained from other electrical manufacturing companies; literature of this class will be valuable for future historical purposes, and the Library of the INSTITUTE would appear to furnish an excellent means for its preservation.

Sets as complete as could be provided have been obtained of the publications of the Underwriters' Electrical Association, the National Board of Fire Underwriters, the International Association of Municipal Electricians, the Massachusetts Board of Gas & Electric Light Commissioners, the League of American Municipalities and of the Municipal Electrical Departments of Philadelphia, Chicago, Detroit and South Norwalk, Conn. In the letter to be sent out with the catalogue of periodicals an appeal will be made to the membership to assist in building up the collection of this class of literature.

The compilation of the Wheeler Bibliography is now approaching completion and the MS. will probably be ready to place with the printer the latter part of the present year.

During the year gifts of books were received from the following:

ARNOLD, BION J.
BOWLER, F. T.
BRILLOUIN, M.
CHEMICAL PUBLISHING COMPANY
CALDWELL, EDWARD.
DODGE, F. M.
EDISON, THOMAS A.
ELLICOTT, E. B.
GODDARD, C. M.
GAUTHIER-VILLARS.
HANCHETT, GEORGE T.
HAMMER, W. J.
HOPPING, G. W.
HUTCHINSON, R. W., JR.
LINDERS, O.
MCGRAW PUBLISHING COMPANY.
MACVICAR, J.
MASSACHUSETTS BOARD OF GAS & ELEC. LIGHT COMMISSIONERS.
MEAD, MORRIS W.
MARTIN, T. C.
MORISON, J.
MULLIN, E. H.
ROEBER, E. F.
SAGER, J. C.
SMITHSONIAN INSTITUTION.
SPANG, H. W.
SYNDICAT DES FORCES HYDRAULIQUES.
TISCHENDORFER, F.
UNDERWRITERS NATIONAL ELECTRICAL ASSOCIATION.
U. S. CENSUS OFFICE.
D. VAN NOSTRAND COMPANY.
VARLEY, S.
WEAVER, W. D.
WILEY, J. & SONS.
WINCHESTER, A. E.
WOLCOTT, TOWNSEND.

As stated in the report last year, the gift of Mr. B. J. Arnold comprises a complete set of "Annalen der Physik" from 1790 to date. Mr. Arnold also defrayed the cost of binding or rebinding a number of volumes of the set, which is now in excellent condition.

Mr. Thomas A. Edison donated a complete set to date of the "Nuovo Cimento." Part of the set came from the library of Mr. Edison, who purchased abroad the volumes necessary to complete the set, and defrayed the cost of binding all the volumes uniformly in half-morocco.

The donation of Mr. Edward Caldwell consists of a set of "Popular Science Monthly," complete to 1900, in new half-morocco binding.

Mr. Edward D. Adams has requested your committee to complete to date at his cost the several sets of Royal Society publications which he presented last year to the Library. Mr. Adams has also very generously offered to subscribe in the name of the Library for the annual issues of the "International Catalogue of Scientific Literature" covering the branches of math-

ematics, mechanics, physics and chemistry, and numbering in these branches about six volumes yearly—the term of a subscription being fixed by the publishing committee at five years. This valuable publication, which supercedes the Royal Society Catalogue, is compiled under the auspices of a principal learned body in each of the leading countries of the world, the Smithsonian Institution representing the United States.

Following are the statistics of the Library brought up to May 1, 1904:

STATISTICS OF LIBRARY.

Source.	Titles.	Volumes.	Pamphlets	Valuation.
Report of May 1, 1903	6377	8139		$16,870.78
PURCHASES:				
Carnegie Fund	14	128		283.17
Donation Fund	114	120		258.62
Mailloux Fund		9		29.20
Institute Appropriation	299	366	22	785.19
Miscellaneous Pamphlets			92	23.00
Periodicals Bound	59	92		184.00
GIFTS:				
B. J. Arnold	1	332		1,304.72
Edward Caldwell	1	57		70.00
Thomas A. Edison	1	47		200.00
Miscellaneous Gifts (33 donors)	58	130		128.00
Total, May 1, 1904	6924	9420	114	$20,136.68
Duplicates	187	424		671.02
	6737	8996	114	$19,465.66
Duplicate Periodical Titles	64			
	6673	8996	114	$19,465.66

Following is the total valuation of the Library including permanent library fixtures:

TOTAL VALUATION.

Books	$20,136.68
Book Stacks	1,470.25
Furniture, Catalogue Cases, etc	130.20
	$21,737.13

Following are tabulations giving the present state of the several funds of which the Library Committee has cognizance:

CARNEGIE FUND.

Dr.		Cr.	
Balance May 1, 1903	$4,864.10	Books	$283.17
Interest to May 1, 1904	135.70	Wheeler Bibliography	284.25
		Unexpended	4,432.38
	$4,999.80		$4,999.80

MAILLOUX ENDOWMENT FUND. ($1,000.)

Dr.		Cr.	
Interest Accrued	$29.50	Subscriptions	$20.20
		Continuation of Sets	9.00
		Unexpended	.30
	$29.50		$29.50

DONATIONS.

Dr.		Cr.	
Balance May 1, 1903	$635.04	Purchase of Books	$265.37
		Unexpended	369.67
	$635.04		$635.04

The table below gives an account of funds appropriated by the INSTITUTE for library purposes:

INSTITUTE APPROPRIATIONS.

Dr.		Cr.	
Balance May 1, 1903	$785.45	Books	$785.19
Appropriation for Maintenance	3,000.00	Rent	1,505.04
Special Appropriation for book stacks	370.00	Insurance	54.77
		Salary, Librarian	780.33
		Extra Assistance	50.00
		Binding	254.20
		Book Stacks	370.00
		Library Supplies	65.36
		Subscriptions	20.00
		Miscellaneous	19.05
		Unexpended	251.51
	$4,155.45		$4,155.45

Annual Appropriation, 1904–1905.

The annual appropriation asked of the Institute for Library purposes is limited to the sum required solely for the maintenance of the Library. It includes no provision for the purchase of books or Library fixtures, nor for any other than routine expenses and binding. The requirements for the fiscal year May 1, 1904, to May 1, 1905, will be as follows, the item for binding including provision for rebinding the Library set of Patent Specifications, which is complete to June 30, 1891, and numbers 97 volumes:

Rent	$1,505.04
Insurance	65.00
Salary, Librarian	780.00
Extra Assistance	50.00
Binding	450.00
Library Supplies	100.00
Subscriptions	25.00
Express, Postage, Miscellaneous	24.96
	$3,000.00

Following is an itemized statement of disbursements from the annual appropriation of last year:

Rent	$1,505.04
Insurance	54.97
Salary, Librarian	780.33
Extra Assistance	50.00
Binding, Periodicals and Books	254.20
Library Supplies	65.36
Subscriptions	20.00
Express, Postage, Miscellaneous	19.05
Unexpended	251.25
	$3,000.00

For the Library Committee,

W. D. Weaver, Chairman.

EXPLANATION.

The following papers are "Introductions" to a discussion to take place at the INSTITUTE meeting at Chicago, June 21-22, 1904. They are not intended to be formal or complete "Papers" but serve merely as a basis or framework for discussion on the subjects with which they deal. All those connected with the INSTITUTE and desiring to take part in this discussion may do so by being present at the meeting or if this is not possible by sending in a written "Contribution."

In contributing to a discussion, whether verbally or in writing, it is requested that the matter under discussion be taken up under the several heads and in the order made use of in the Introduction, and that following the treatment of these heads there be introduced any other matter which the Contributor may deem advisable. When the Contributions are made by mail on more than one of the topics under consideration at the same meeting, it is requested that the several Contributions be embodied in separate letters.

Contributions will be read at the meeting for which they are intended either in full, in abstract, or as part of a general statement giving a summary of views of those taking the same position in the matter under discussion.

It should be borne in mind that the Introductions are written in order to provoke discussion and that there should be no hesitancy in attacking them if they do not agree with the opinions of the Contributor. On the other hand, if the Contributor agrees with the matter of the Introductions, either as a whole or in part, he should state the fact.

It should also be borne in mind that the principal object of this scheme is to enable and encourage those not in a position to attend meetings to take part in the discussion. If one does not feel himself qualified to discuss certain portions of an Introduction, but is able to discuss other parts, it is to be hoped he will contribute to the latter.

Contributions to the discussion of these papers should be mailed to Ralph D. Mershon, 29 Broadway, New York. so that they will be received not later than June 17, 1904.

A paper to be presented at the 188th Meeting of the American Institute of Electrical Engineers, Chicago, June 21-22, 1904.

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PROTECTION OF CABLES FROM ARCS DUE TO THE FAILURE OF ADJACENT CABLES.

BY W. G. CARLTON.

The matter of the protection of cables depends largely on the number of cables and amount of room available. This protection is needed in stations and sub-stations, also in manholes on underground work; on inside work there is generally available room for separating the cables, and for this reason it is easier to take care of them than in underground work. In general, similar protection can be used in either place, except that in underground work material must be used which will not be affected by water, as manholes are liable to be flooded. Protection of cables in manholes will be considered particularly.

In old conduit systems where a large number of ducts have been installed and no attempt made at separating them as they enter manholes, it is a difficult matter to protect cables. If, however, the work has been carefully laid out, plenty of room taken in manholes and the ducts spread so that there is a vertical space of from 8 in. to 12 in. between the two halves of the conduit line, it is much easier to ensure satisfactory protection. It should be borne in mind that a conduit line of a large number of ducts is not a desirable thing. Two independent lines will cost considerably more than a single line of the same capacity, but this extra cost is an insurance against future trouble.

On account of the large amount of energy carried by high-pressure cables their protection is of the utmost importance. High-pressure transmission cables operate usually at from 5000 to 15 000 volts and are nearly always three-conductor cables. It is to the protection of such cables that this paper refers particularly, although it will generally be found that protection

is needed more from burn-outs on low-pressure cables than from those on high-pressure ones. High-pressure cables are usually protected by automatic overload devices and, if these are satisfactory they will disconnect the cable before any large amount of damage is done. On the other hand, low-pressure cables may continue to burn without drawing enough current to cause them to be cut off. Cables generally break down in manholes due to poor work in jointing or to careless handling during installation. Various methods are in use for fireproofing and isolating them from one another.

A method employed in a number of places is to wrap the cables with asbestos paper or tape about 1/8 in. thick, using two layers and binding the asbestos on by means of steel or brass tape. The metal tape is wrapped either in an open spiral leaving an inch or more between turns, or with the edges touching leaving no open space. With the metal tape wrapped close there is less danger of the asbestos disintegrating on account of water in manholes or of other causes. The asbestos wrapping should be carried well into the duct. This protection has been found adequate by several large companies. Its life, however, is uncertain, particularly on underground work. One disadvantage is that in the case of loaded cables the heat is less easily radiated on account of the asbestos covering. Asbestos paper soaked in silicate of soda has been used for wrapping cables; this has the advantage of not requiring any metal tape for a binder, as the paper treated in this manner is cemented to the cable. It is doubtful if the silicate of soda treatment will be satisfactory for use in flooded manholes, although it will be in dry places.

A second method of isolating and protecting cables consists in providing separate chases or runways for them. Sometimes this is done by building special long and thin bricks into the wall of the manhole leaving them projecting so as to form a shelf. Soapstone slabs are also laid in the wall forming shelves or boxes for the cables. The cables may be further protected with asbestos if desired. It is difficult with this method of protection to make a satisfactory job where the cables enter the ducts unless there has been a very elaborate spreading of the ducts.

The third method of protection, which is very satisfactory when the cables run nearly straight through the manholes, consists of a covering of vitrified-clay tile. Ordinary single-duct

clay tile in 18 in. lengths is used, the tile being cut nearly through before baking so that it is easily broken in halves. The tile on the lower layer of cables is supported by means of light galvanized angle-irons run longitudinally through the manholes. The upper layers are supported on the lower ones. For the bends in the cables 45 degrees curves with a 12 in. radius are used. These curves being laid in reverse similar to the letter "S" near the end of the manholes where the cable enters the duct. The tiles are laid in cement mortar forming a good mechanical piece of work and giving practically a conduit line through the manhole. One or two of the lower ducts should be left open at each end of the manhole for a space of about one-half inch so that water will drain from the conduit line. The principal objection to the use of tiling is, that in the case of trouble, making it necessary to remove a cable, the tiling must be broken out. Iron brackets are avoided by the use of tiling and there is no chance for current to flow from the lead sheath of one cable to that of another except such leakage as may occur due to moisture in the ducts. Personally the writer is in favor of using the split-clay tile covering where possible, and asbestos paper and brass tape in other places.

High-pressure cables should be covered, not only to protect them from the failure of adjacent cables but also on account of the dangers which may arise from an unconfined arc. Oscillations may set up which will produce pressures many times in excess of that at which the cable is working, and these high-pressures are liable to break down the insulation on the cables or on the switchboard apparatus, transformers, or generators, which may be connected to the cables. For this reason one large company in New York has installed on all cables within a mile of the power-house, in addition to the regular asbestos covering, a sheet-iron armor 1/16 in. thick. This armor being rolled and especially prepared to meet curves or bends in the cable, each section lapping the next one. This sheet-iron is clamped together so as to make a strong, mechanical covering.

A manhole fire causes more trouble at the top of the hole than lower down, and for this reason the most important cables should be kept towards the bottom of the manhole. In the case of large manholes it will often be found desirable to build a partition wall longitudinally through the hole, making practically two manholes.

While burn-outs in cables are bound to occur,—and for this

reason, fireproofing cables, particularly important ones, is necessary,—at the same time, the number of burn-outs can be kept to a minimum by careful work. Only experienced and careful men should be allowed to train cables. The manhole should be built so that it is not necessary, or even possible, to make a short bend in the cable in taking it from the duct to the side of the hole. The jointing should be done by thoroughly reliable men and they should be given to understand that it is not speed which is wanted but first-class work. If it is not desirable to do the jointing as soon as the cables are pulled in, the ends should be sealed, first cutting them back far enough to be positive that there is no moisture present. Tests for moisture should be made if there is any reason to suspect its presence.

The experience of one company in Chicago has been that nearly all trouble that has occurred on three-conductor high-pressure cables has been due to defective joints, to moisture in the cables near the joints, or to sharp bends in the cable. Some burn-outs have occurred due to the lead sheathing of the cables being damaged by electrolysis. This can be prevented by grounding the lead of the cables at suitable intervals or by insulating them if possible. Frequent inspection should be made to determine whether the lead sheaths of the cables are carrying current, a recording voltmeter having a total range of from three to five volts will be found convenient for this work and a chart covering the entire day will be found much more valuable than a few single readings.

A paper to be presented at the 188th Meeting of the American Institute of Electrical Engineers, Chicago, June 21-22, 1904.

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SYNCHRONOUS MOTORS FOR REGULATION OF POWER-FACTOR AND LINE PRESSURE.

BY B. G. LAMME

It is well known that the synchronous motor, running without load on an alternating-current circuit, for instance, can have its armature current varied by varying its field strength. A certain adjustment of field strength will give a minimum armature current. Either stronger or weaker fields will give increased current. These increased currents are to a great extent wattless. If the field is weaker than the normal (or field for minimum armature current), the increased armature current is leading with respect to the e.m.f. waves in the motor and lagging with respect to the line e.m.f. The current in the motor is therefore corrective in its nature. For stronger than the normal field, the current is to a great extent lagging and tends to lessen the flux in the motor and the current is leading with respect to the line e.m.f. A synchronous motor therefore has an inherent tendency to correct conditions set up by improper adjustment of its field strength. The correcting current in the motor is drawn from the supply system and this current also has a correcting effect on the supply system, tending to produce equalization between generated pressures in the motor and the supply pressure. This characteristic of the synchronous motor can readily be utilized for two purposes; namely, for varying the amount of leading or lagging current in a system for producing changes in the power-factor of the system (including transmission line, transformers, and generators), or a synchronous motor can be utilized for pressure regulation in a system.

As the synchronous motor can be made to impress a leading current upon the system, and as the amount of this leading current will depend upon the field adjustment of the synchronous motor, it is evident that this property can be used for neutralizing the effects of lagging current due to other apparatus on the system. The resultant leading or lagging current can be varied and the power-factor controlled over a fairly wide range depending upon the location of the synchronous motor or motors, and upon the current capacity of the motor, etc.

As the wattless current in the motor is primarily a corrective current, it is evident that for most effective purposes for adjusting power-factor on the system the corrective action of this current on the motor should not be too great. When used for such purpose the synchronous motor should therefore be one which would give a comparatively large current if short-circuited as a generator. Also the motor should preferably be one in which the magnetic circuit is not highly saturated, for in the saturated machine the limits of adjustment in the field strength are rather narrow.

As has been noted above, if the field strength of the motor be varied, a leading or lagging current can be made to flow in its armature circuit, this current being one which tends to adjust the pressure of the armature and that of the supply system. It is evident that if the armature pressure is held constant and the supply pressure varied, a leading or lagging current would also flow. If for instance the line pressure were dropped below that of the motor, then a lagging current would flow in the motor tending to weaken its field, and a leading current would flow in the line, tending to raise the pressure on the line. If the line pressure should be higher than that of the synchronous motor, then the current in the motor would be leading, tending to raise its pressure; while it would be lagging with respect to the line, tending to lower its pressure. The resultant effect would be to equalize the pressures of the line and motor, and there would thus be a tendency to regulate the line pressure to a more nearly constant value. It is evident that the less the synchronous motor is affected by the corrective current and the more sensitive the line is to such corrective action, the greater the tendency will be toward constant pressure on the line. It is therefore evident that the synchronous motor which gives the largest current on short circuit as a generator would be the one which gives the greatest corrective action as regards pressure regulation of the system.

For such regulation, the synchronous motor which gives a comparatively large leading or lagging current with small change to the pressure of the system is the most suitable one. Or, the motor which gives the greatest change in the leading or lagging current is the one which gives best regulation. It is the change in the amount of wattless current which produces the regulation. This current could vary from zero to 100 leading, for example, or could change from 50 leading to 50 lagging, or could change from 100 lagging to zero lagging. Any of these conditions could produce the desired regulating tendency, but all would not be equally good as regards the synchronous motor capacity. If in addition to the regulating tendency it is desired to correct for lower power-factor due to other apparatus on the circuit, it would probably be advisable to run a comparatively large leading current on the line due to the synchronous motor, and the regulating tendency would be in the variations in the amount of leading current, and not from leading to lagging, or *vice versa*. A larger synchronous motor for the same regulating range would be required than if the motor were used for pressure regulation alone. It is evident that the current capacity of a motor regulating from 50 leading to 50 lagging need be much less than for current regulating from 100 leading to zero. It is evident therefore that if there is to be compensation for power-factor as well as regulation of pressure, that additional normal current capacity is required.

In case such synchronous motors are required for regulation purely, it may be suggested that such machines be operated at very high speeds compared with ordinary practice. At first glance it would appear that such a synchronous motor could be operated at the highest speed that mechanical conditions would allow, but there are other conditions than mechanical ones which enter into this problem. For instance, it is now possible to build machines of relatively large capacity for two poles for 60-cycle circuits, and for very large capacities—say 1500 kilowatts—having four poles. Therefore mechanical conditions permit the high speeds, and the electrical conditions should be looked into carefully to see whether they are suitable for such service. As such synchronous motors should give relatively large currents on short circuit the effect of high speeds and a small number of poles on short-circuit current should be considered.

In order to give full-load current on short circuit, the field

ampere-turns of such a machine should be practically equal to the armature ampere-turns, taking the distribution of windings, etc., into account. By armature turns in this case is not meant the ampere wires on the armature, but the magnetizing effect due to these wires. Therefore to give, for instance, five or six times full-load current on short circuit, the field ampere-turns should be relatively high compared with the armature. This means that the field ampere-turns per pole should be very high, or the armature ampere-turns per pole very low. Experience shows that for very high speed machines, such as used for turbo-generators, there is considerable difficulty in finding room for a large number of field ampere-turns, and therefore in such machines it is necessary to reduce the armature ampere-turns very considerably for good inherent regulating characteristics. This in turn means rather massive construction, as the magnetic circuit in both the armature and field must have comparatively large section and the inductions must be rather high. This in turn means high iron losses in a relatively small amount of material compared with an ordinary low-speed machine, and abnormal designs are required for ventilation, etc., and for mechanical strength.

An increase in the number of poles usually allows increased number of field ampere-turns without a proportionate increase in the number of armature ampere-turns. This condition is true until a large number of poles is obtained when the leakage between poles may become so high that the effective induction per pole is decreased so that there is no further gain by increasing the number of poles, unless the machine is made of abnormal dimensions as regards diameter, etc. Experience has indicated that in the case of very high-speed and very low-speed alternators, it is more difficult to obtain a large current on short circuit than with machines with an intermediate number of poles. For example, it is rather difficult to make a 600 kilovolt-ampere, 3600-rev. per min., 2-pole machine which will give three times full-load current on short circuit. A 4-pole, 1800 rev. per min. machine can more easily be made to give three times full-load current on short circuit and with comparatively small additional weight of material. The material in the rotating part of the four-pole machine, while of greater weight, may be of considerably lower cost per pound. The stationary part of the four-pole machine may have a somewhat larger internal diameter, but the radial depth of sheet-steel will be less

than in a two-pole machine. The total weight of material in the armature of a four-pole machine may be practically no greater than in a two-pole machine. Therefore a two-pole machine of this capacity should cost more than a four-pole machine, if designed to give the same current on short circuit. A six-pole machine would show possibly a slight gain over the one with four poles, but not nearly as much as the four-pole machine would over the one with two poles. The real gain of the six-pole over the four-pole construction would be in obtaining a machine which would give more than three times full-load current on short circuit. It would possibly be as easy to obtain four times full load current on short circuit with a six-pole machine as to obtain three times full load current on four-pole machine. An eight-pole machine would be in the same way somewhat better than the six-pole machine. Therefore if a 600 kilovolt-ampere machine giving six times full-load current on short circuit is desired, it would be advantageous to make the machine with possibly eight to twelve poles. The question of which would be the cheaper would depend upon a number of features in design.

If very large short-circuit currents are desired, then, as indicated above, the number of poles for a given capacity should be increased, or the normal rating of the high-speed machine should be decreased. If, for example, the 600 kilovolt-ampere, 3600 rev. per min. machine, mentioned above, should be rated at 200 kilovolt-amperes, then it could give nine times full-load current on short circuit; but such a method of rating is merely dodging the question.

In general, the following approximate *limits* for speeds and short circuit currents for 40-cycle apparatus can be given. These limits are necessarily arbitrary, and are intended to represent machines which could probably be made without using too abnormal dimensions;

600 kilovolt-amperes, 3600 rev. per min., two to three times full-load current on short circuit.

1000 kilovolt-amperes, 1800 rev. per min., three to four times full-load current on short circuit.

1500 kilovolt-amperes, 1200 rev. per min., four to five times full-load current on short circuit.

2500 kilovolt-amperes, 900 rev. per min., four to five times full-load current on short circuit.

For 25 cycles it is more difficult to give limiting conditions,

as the choice of speeds is very narrow. If, for example, a 1500 kilovolt-ampere, 2-pole, 1500 rev. per min. machine can be made to give three times full-load current on short circuit, then as machines of smaller rating cannot run at higher speed, the limiting condition of such machines must be the amount of current which they will give on short circuit. In the same way a 4-pole machine running at 750 rev. per min. may be made for 5000 kilovolt-amperes for three times full-load current as the limiting rating, and there is no choice of speeds for ratings between 1500 kilovolt-amperes and 5000 kilovolt-amperes.

It should be noted that the above speeds are very high compared with ordinary alternator practice and are up to high-speed turbo-generator practice, but machines with the above short-circuit ratings and speeds are probably more costly to build than machines of corresponding ratings at somewhat lower speeds. It will probably be found therefore that for the above maximum current on short circuit the cheapest synchronous motors for the given ratings will have somewhat lower speeds than those indicated above. It is certain that the lower-speed machines will be easier to design and will be slightly quieter in operation. Probably best all-round conditions will be found at about half the above speeds.

The above limiting conditions are given as only approximate and are based upon machines having ventiliation as is usually found on rotating field generators for high speed. Artificial cooling, such as obtained with an air-blast or blowers could modify the above figures somewhat; but in general it has been found that high-speed alternators can be worked up to the limit imposed by saturation before the limit imposed by temperature is attained. Therefore if higher saturation is not permissible, then there may be relatively small gain by using artificial cooling.

One of the principal applications of such regulating synchronous motors would be for controlling or regulating the pressure at the end of a long transmission line for maintaining constant pressure at the end of the line, independent of fluctuations of load or change of power-factor. In this case, increased output of the transmission line may more than compensate for the cost of the regulating synchronous motor. In such a case the synchronous motor not only acts as a regulator on the system but costs nothing in the end. In general, the more current that such a synchronous motor will give on short-

circuit, the better suited it will be for its purpose at the end of a long transmission line.

Where a number of such synchronous motors are installed in the same station, the field adjustment must be rather carefully made, to avoid cross-currents between machines; and the saturation characteristics of the various machines should be very similar. The better such machines are for regulating purposes, the poorer they are for equalizing each other by means of cross-currents.

As to the use of dampers with such synchronous motors, it is difficult to say just what is required. A synchronous motor on a line with considerable ohmic drop is liable to hunt to some extent, especially if the prime mover driving the generator has periodic variations in speed. If the synchronous motor gives very large current on short circuit, then its synchronizing power is high; this will tend to steady the operation of the motor and decrease the hunting. The writer believes that such motors in practice will be found to operate better and have better regulating power for constant pressure if provided with rather heavy copper dampers effectively placed on the field poles. With such heavy dampers reaction of the armature on the field is retarded, and therefore the armature may give a larger momentary current than would flow if there were no damping effect; in other words, the motor is more sluggish than one without dampers. Therefore the addition of heavy dampers on such a machine may produce the same regulating effect which would be obtained by a machine without dampers which gives a larger current on short circuit. Also a machine with heavy dampers will usually be the one with the least hunting tendency and therefore will have the least effect on the transmission line due to hunting currents.

In the above, the synchronous motor has been considered only as a regulator and not as a motor. It may be worth considering what would be the effect if the synchronous motor can do useful work at the same time that it regulates the system. In this case, with a given rated output, one component of the input will be wattless, and the other part will be energy. The ratio of these two components could be varied as desired. For example, considering the input as 100, the wattless component could be 60 when the energy component is 80; or the synchronous motor could carry a load of 80% of its rated capacity, this load including its own losses, and could

have a regulating component of 60% of its rated capacity. If the motor is used as a regulating machine only, then its wattless component can be practically 100. It appears therefore that the machine could be used more economically as both motor and regulator than as a regulator alone, but in such case it would probably be advisable to run the motor at somewhat lower speed than if operated entirely as a regulator. This reduction in speed may practically offset the gain in apparent capacity by using the machine for a double purpose. Also there is comparatively limited use for large synchronous motors for power purposes, as better results are usually obtained by subdividing the units and locating each unit nearest to its load. If a load could be provided which would permit very high-speed driving, then it would probably be of advantage to utilize the synchronous motor for driving.

As the synchronous converter is one form of synchronous motor, the question of utilizing such machines for regulators should be mentioned. Upon looking into the question of distribution of losses in the converter, it will be noted that the losses in the armature winding are not uniform. Investigations show that at 100% power-factor, the lowest heating in copper is obtained, and that any departure from this power-factor shows considerably increased loss in the copper, such loss being very high in certain portions of the winding. Next to the taps which lead to the collector there are strips of winding which at times are worked at a very high loss. Experience shows that it is not advantageous to operate converters at a low power-factor, and that if so operated continuously, or for any considerable periods, the winding should be made much heavier than for higher power-factors. Also in the usual design of converters the field is not made as strong compared with the armature as in alternator practice, and therefore the regulating tendency of the converter compared with a generator or ordinary synchronous motor, is low. Synchronous converters can and do act as regulators of pressure for sudden changes of the supply pressure, but such correcting or regulating action should not be continual; that is, the pressure supplied to a converter from a line should nominally be that required by the converter for best operation as a synchronous converter. Unless designed for the purpose, a synchronous converter should not be used to correct low power-factors due to other apparatus on the circuit.

In the above considerations only general reference has been made to the cost of synchronous motors for regulating pressure and power-factors. It is difficult to give even approximate figures for relative costs of such apparatus. As intimated before, there is some mean speed or number of poles which will be the most suitable for giving a certain maximum current on short circuit. For speeds slightly above or below such mean speed, the cost of the synchronous motor should vary almost in proportion to the speed, provided the maximum short-circuit current can be diminished somewhat at the same time. If the speed is further increased or further decreased, the cost will tend to approach a constant figure. As the extreme conditions are approached, the cost will begin to rise. The above assumptions are on the basis of continuous operation at a given current capacity, this being the same in all cases. The above assumption is on the basis of decrease in the maximum short-circuit current, as the machine departs from the mean, or best speed. If the same maximum current is required, then the lowest cost should be at the mean or best speed, while at either side the cost should rise.

It is evident that it would be difficult to give any figures on relative costs of such apparatus. The machine for the best or mean condition, should cost practically the same as an alternating-current generator of the same speed, output, and short-circuit characteristics. As this speed would probably be somewhat higher than usual generator speeds, the cost of such machine would therefore be somewhat lower. This cost would be to a considerable extent, a function of the current on short circuit for a given rated capacity of machine. As mentioned before, in giving a table of limiting speeds and short circuits, it is probable that one-half this limiting speed would be near the best condition. Such machines would probably cost from 60% to 80% as much as similar machines for usual commercial high-speed conditions, neglecting turbo-generator practice. The frequency has considerable effect on this, as, for example, there is small choice of speed as regards high-speed 25-cycle machines. Taking very general figures only, it is probable that in the case of a given capacity of machine for say three or four times full-load current on short circuit the cost cannot be expected to be lower than one-half that of machines of similar rating at ordinary commercial speeds, turbo-generator practice being excluded. The costs in general should approximate more nearly

those of turbo-generators; but again, an exact comparison cannot be made because in usual practice the turbo-generators do not give three to four times full-load current on short circuit.

There are a number of other conditions in this general problem, such as advantage or disadvantage of placing synchronous motors in the main power-house, and distributing them in a number of sub-stations. Also there is the question of the effect of the cost on the generating plant when used with such regulating synchronous motors. If higher power-factors are maintained on the transmission system and generator, a cheaper form of generator can probably be used. The high power-factor permits a larger output from the transmission system and thus represents a gain. If the synchronous motor can be operated at its best speed and also do work, then there is a further gain. If the synchronous motor should be located at the center of power distribution, and the power is distributed through induction motors, then there is a possibility of reducing the cost of such motors by lowering the power-factor, this being compensated for by the synchronous motor delivering leading currents. As the cost per horse power of small motors will be much greater than the cost per horse power of a large regulating motor, there is a possibility of gain from this source. If the induction motors are distributed over wide territory, this gain would be lessened and might disappear.

It should be mentioned that the power-factor of a system as influenced by difference in wave form has not been considered in the preceding discussion. It is obviously impossible to neutralize by a synchronous motor the effect of currents in a system due to difference in wave form. Such currents will in general be of higher frequency than the fundamental wave of the system, and the synchronous motor obviously could not correct for them, unless it impressed upon the system opposite waves of the same frequency. This would mean a synchronous motor with a different wave form from that of the system.

The power-factor of a system will also be affected by any hunting of the apparatus on the system. It is evident that the synchronous motor could not correct or neutralize such effects, except through exerting a damping effect on the system and other apparatus on the system. A synchronous motor with heavy dampers can reduce the hunting in a system, but such hunting can also be damped by induction motors with low-resistance secondaries, especially if of the cage type. This

correcting effect should therefore be credited to the damper rather than to synchronous-motor action. There are a number of other questions which arise in connection with this regulating feature of the synchronous motor, but the subject is too broad to permit even mention of them.

The substance of the preceding statements can be summarized as follows:

1. A synchronous motor can be used to establish leading or lagging currents in its supply system by suitable field adjustment, and can thus affect or control power-factor or phase relations of the current in the alternating-current system.

2. A synchronous motor will set up leading or lagging currents in its supply system if its field strength is held constant, and the pressure of the supply system is varied above or below that generated by the synchronous motor. Such leading or lagging currents in the supply system will tend to vary the pressure of the system. A synchronous motor can thus act as a regulator of the pressure of its supply system.

3. This regulating action is greatest with synchronous motors which have the closest true inherent regulation (as indicated by high field magnetomotive force compared with the armature magnetomotive force) in distinction from machines which have close apparent regulation obtained by saturation of the magnetic circuit.

4. If the synchronous motor is used both for regulating the power-factor for neutralizing the effect of other apparatus on the circuit, and for regulating or steadying the pressure of the supply system, its normal capacity for regulating will be diminished.

5. The most suitable speeds for best electrical conditions will in general be considerably below highest possible speeds as limited by mechanical conditions.

6. Heavy dampers will increase the effectiveness of the regulating tendency.

7. If the synchronous motor can be used for power purposes as well as for regulation, its apparent capacity is increased. This is due to the fact that the regulation is obtained by means of a wattless component and the power from the energy component, and the algebraic sum of these two is greater than their resultant which fixes the current capacity of the machine.

8. Synchronous converters in general are not suited for regulating the pressure or controlling the power-factor of an alternating-current system.

9. The costs of synchronous motors for regulating purposes will in general be lower than for alternating-current motors or generators of customary speeds, and will approach more nearly to turbo-generator practice.

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LONG SPANS FOR TRANSMISSION LINES.

BY F. O. BLACKWELL.

Many cities to-day are dependent for their lighting, transportation, water supply, and the operation of their industries upon electric power transmitted over considerable distances.

Unfortunately interruptions of the power service do occur not infrequently and when they do happen they so inconvenience the public as to be most conspicuous. The impression that long-distance power transmissions are unreliable has some basis of fact that seriously interferes with their development. Although absolutely continuous service may not be possible, many of the troubles now experienced can be either altogether eliminated or greatly reduced. Among the principal causes of interruption, so far as the line is concerned, may be mentioned:

Short circuiting of lines by branches of trees, wires, or by large birds getting across them.

Burning of wooden pins, cross-arms, and pole-tops by leakage or electrostatic discharges from the conductors.

Burning of wooden poles at the ground from forest or prairie fires.

Failure of insulators from puncture by the current, or their destruction by missiles, discharged maliciously.

Lightning damaging the appartaus connected to the circuits and sometimes destroying poles.

Accidents due to heavy winds overturning the poles or to floods washing them out.

The deterioration of a line requires its replacement in from five to twenty years, depending on climatic conditions and the material which is used in its construction. This replace-

ment of the poles with new ones can only be done by shutting off the current or at the risk of accidental interruptions. Let us see what can be gained by substituting a steel tower construction with long spans for a wooden pole line.

Short circuits are by far the most common difficulty, the only remedy for which is to put the wires so far apart that they are unlikely to be bridged across. This can readily be done even with more than one circuit when a steel cross-arm is employed. Burning is of course entirely done away with where metal construction is used.

Failure of insulators from electrical causes can be obviated by getting larger and better insulators; this is practicable where the spans are long and the number of insulators is small. Insulators on high towers are much poorer targets than when they are near the ground and so are less liable to be broken.

Each metal tower is a lightning arrester and as they are the highest points in the line they materially assist in its discharge; the tower itself, being a conductor, cannot be injured by lightning. Steel structures can be exactly figured to meet safely any strains that can come upon them and can generally be located only at safe places where there is no danger of washouts. The deterioration of a properly constructed and well-galvanized steel tower is very slight, as is proved by marine and windmill experience, and is practically negligible so far as the pins and cross-arms are concerned. Any part of a steel tower can be readily removed and replaced without interrupting the service.

By far the greatest gain obtained from long spans is in the reduction of the number of parts. If one insulating support takes the place of four or five, line troubles will be reduced nearly in direct proportion; the inspection and repair of the line will be much simplified and its cost of maintenance correspondingly diminished.

Cost of Towers.

The cost of a tower construction as compared with wooden poles depends on the locality. Where the right kind of timber exists, it is of course cheaper; but in tropical countries where wooden poles would have to be transported long distances the towers are much less expensive. In addition, to obtain long life a creosoted wood only could be employed and this still further increases the expense. The fewer insulators and pins and the ease of transportation and erection are in favor of towers. They can be packed in light bundles suitable

for mule-back transportation and quickly put together even in the most inaccessible places. Even where the cost of the tower construction is greater it is often justified by the greater certainty of operation which it insures and the lower cost of maintenance.

Strength of Conductor.

The first and most important consideration for long spans is the material of the conductor. Copper, aluminum, and iron are availiable for this purpose. Various alloys of copper have great strength, but their conductivity is too low and their cost too high to compare favorably with the more common metals. Copper wire varies widely in its characteristics depending on the methods used in its manufacture. The copper is received at the wire-mill in the form of cast-wire bars weighing 300 to 350 lb. It is then rolled into rods and the rods are drawn into wire of the required size. The temperature at which the metal is rolled, the reduction of area both in rolling and drawing, and the amount of annealing which the wire is given—all have an important bearing on its characteristics. As the size of the original wire bar is limited the smaller the wire, the more it is worked and in general the better the result. Cable made up of several strands has the advantage of using smaller wires than a solid conductor and also permits of longer lengths of conductor without splices. Assuming a 300-lb. wire bar, a 19-strand cable for example can be made up weighing 5700 lb. while if solid wire were used the weight of one piece would be 300 lb. In other words, there would be 19 times as many joints with the solid wire as with the 19-strand cable. The smaller the wire and the greater the strength, the more brittle it becomes. This is partially compensated for by the greater flexibility of a cable and the fact that a strand can break without the whole conductor parting.

Each strand should be a continuous wire without joints. Joints in the cable should be as few as possible and made by means of sleeves, as brazing or soldering anneals the wire and much reduces its strength. The permissible tension in the cable must not exceed the elastic limit, by which is meant the point at which the material will continue to elongate and will eventually break, and not the usually accepted meaning of elastic limit as that point at which the strain ceases to be proportional to the stress. Copper cable recently made for a transmission plant with spans of 500 feet had an elastic limit of 40 000 lb.

per square inch; similar aluminum cable had an elastic limit of 12 000 to 14 000 lb. per square inch; galvanized iron telegraph has an elastic limit of 35 000 lb. The ultimate tensile strengths of these wires were 60 000 lb. for copper, 24 000 lb. for aluminum, and 55 000 lb. for iron.

The advantage of aluminum is that it weighs less than copper for the same conductivity, but for long spans its lesser strength, greater diameter, and higher coefficient of expansion are against it. Steel wire has about nine times and iron wire or cable about six times the resistance of copper so that they are more expensive as a conductor than copper. In order to avoid oxidization it is necessary to galvanize iron or steel wire; this partially anneals it and reduces its strength. There are cases where the size of high-pressure line conductors is determined not by resistance but by mechanical strength, and in such cases iron or steel wire can be used to advantage.

Elasticity.

The elasticity of the conductor is of considerable value in reducing the sag when the stress is removed, as will be shown later. The elongation of the wire under stress is less after it has once been stretched. The elasticity of cable is greater than that of solid wire but both wire and cable take a set under any stress to which they may be subjected. In the following table is given the modulus of elasticity of copper, aluminum, and iron wire.

Copper hard-drawn wire	19 500 000
Aluminum hard-drawn wire	10 200 000
Iron hard-drawn telegraph wire	24 0000 00
Copper hard-drawn cable wire	16 300 000

Each sample was stretched to a point somewhat below its elastic limit before testing. It will be noted that the copper cable is considerably more elastic than the solid copper wire, the latter being a strand of the cable. The aluminum wire was of nearly the same conductivity as the copper-wire strand and presumably would have had a lower modulus of elasticity if made up into cable. Aluminum is considerably more elastic and has a decided advantage over copper in this respect.

Coefficients of Expansion.

The coefficients of expansion for Fahrenheit degrees are as follows:

Copper	0.0000096
Aluminum	0.0000114
Steel	0.0000064

As the worst condition so far as sag is concerned is reached when the conductor is hot, a low temperature expansion is most desirable for long spans, and steel is in this respect better than either copper or aluminum.

Strains in Conductors.

The strains upon the conductor are those due to its own weight and the wind acting upon its surface. In a cold climate in addition sleet may form upon the wire, increasing the weight and the surface exposed to the wind. On a line carrying any considerable amount of power it is improbable that sleet will ever form on account of the losses in the conductor slightly heating it. In order to be on the safe side, however, it is best to assume in the North a coating of ice one inch thick all around the conductor. The wind velocity could never exceed 100 miles an hour which would give a pressure of 40 lb. per square foot on a flat surface, or 20 lb. on a cylindrical surface such as that of a wire. The weight is of course a vertical stress and the wind a horizontal one at right angles to the wire. The greatest strain is caused by the resultant of these two. The worst conceivable condition is sleet on the wire, followed by extreme cold weather with high winds. Under such conditions the probabilities are that the ice on the conductor would break off, but without some data on the subject it is hardly safe to assume that this would be the case. In warm climates the absence of sleet and the lesser range of temperature make permissible longer spans than in cold climates.

Sag of Wire.

The maximum sag may be due to the conductor being loaded with sleet or to heating of the wire in a hot sun. The latter will generally be found to give the greater sag. Owing to the conductor being elastic it is not necessary to consider the greatest deflection from a horizontal line between supports as the vertical sag of the wire. The wind pressure causes the wire to swing to one side and it is elongated by the combined strain of wind and weight, but as soon as it is relieved of the wind pressure it swings back to a vertical position and contracts to the length required to carry its weight alone. The sag due to heating of the wire is also somewhat less than it otherwise would be, because when expanded the strain is less and the wire contracts

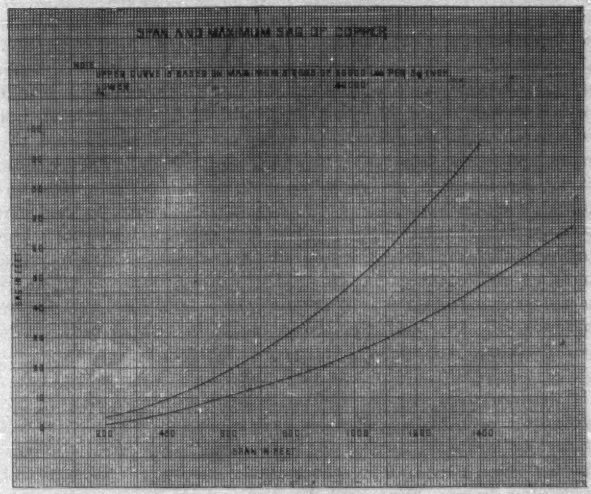
The extreme variation of temperature of the air in cold climates is about 150° fahr., while farther south it does not exceed 100° fahr. To this must be added something for a metal con-

ductor exposed to a hot sun. There are no data upon this but a total variation of temperature of the conductor of 175° fahr. should be sufficient in any country.

Span and Sag Curves.

The attached curves of span and sag are based on the following data:

	Aluminum	Copper
Area 6-strand cable	0.21 sq. in.	0.132 sq. in.
Diameter 6-strand cable	0.59 in.	0.51 in.



Weight per foot	0.240 lb.	0.509 lb.
Elastic limit	12 000 lb.	40 000 lb.
Stress at 1/2 elastic limit	1267 lb.	2640 lb.
Stress at elastic limit	2534 lb.	5280 lb.
Wind pressure per sq. ft.	40 lb.	40 lb.
Wind pressure per ft. cable	0.98 lb.	0.84 lb.
Coefficient of expansion		0.0000096
Variation in temperature	150° fahr.	150° fahr.
Modulus of elasticity	8 000 000	16 000 000

The equations from which the curves were calculated are given below and alongside of them is an example of a 1000-ft. copper span.

$$D = \frac{S^2 \times W}{8\ T} = \frac{1000^2 \times 0.98}{8 \times 2640} = 46.4 \text{ ft.}$$

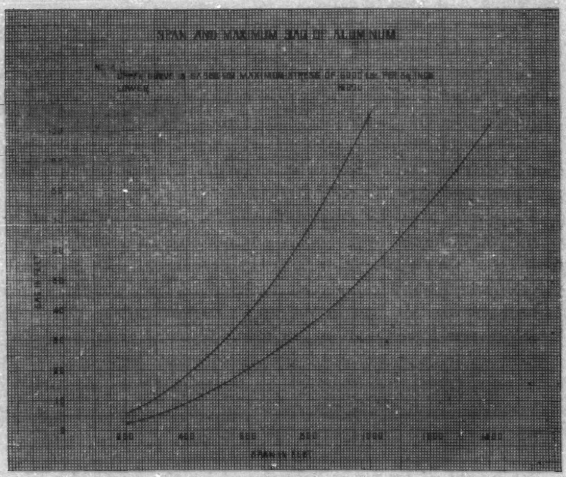
In which D = deflection in ft.

S = span in ft.

W = resultant of weight and wind in lb. per ft. of cable

and

T = stress allowed in cable



$$L = S + \frac{8\ D^2}{3\ S} = 1000 + \frac{8 \times 46.4^2}{3 \times 1000} = 1005.74 \text{ ft.}$$

In which L = length of cable, cold.

$$L_0 = \frac{L}{1 + \frac{F}{E}} = \frac{1005.74}{1 + \frac{20\,000}{16\,000\,000}} = 1004.38 \text{ ft.}$$

In which L_0 = length of cable without stress

F = lb. per sq. in. permitted in cable

and E = modulus of elasticity

$L_H = L_0(1+C \times B) = 1004.38\ (1+0.000009 \times 150). = .1005.81$ ft.
In which L_H = length of cable, hot (150° fahr. rise in temperature)
C = coefficient of expansion
and B = maximum degrees rise in temperature

$$D^3 + \frac{3S}{8}(S - L_H)\,D = \frac{3\,S^3\,L_H\,W}{64\,E\,A}$$

$$D^3 + \frac{3 \times 1000}{8}(1000 - 1005.81)\,D = \frac{3 \times 1000 \times 1005.81\ W}{64 \times 16\,000\,000 \times 0.132}$$

$$D^3 - 2178.7\,D = 22323\,W$$

In which A = area of cable.

From this equation any deflection of the cable can be assumed and the corresponding weight calculated. For instance, in the example if $D = 48.8$ ft., $W = 0.51$ lb.; that is the sag hot without wind is 48.8 ft. and this is the maximum vertical deflection under the conditions assumed.

If $D = 51.1$ ft., $W = 0.98$ lb. which is the maximum deflection with wind but this is at an angle of 31° from the horizontal and the vertical sag is only 26.6 ft.

The curves give the maximum sag for copper and aluminum cables at different spans with an increase of temperature of 150° fahr. above the minimum temperature. The stresses at the minimum temperature due to wind and weight are limited to half the elastic limit in the upper curves and to the elastic limit in the lower curves. The modulus of elasticity of the copper cable was obtained by experiment, but that of the aluminum cable was assumed by considering its elasticity to increase as much as copper cable compared with solid copper wire.

Height of Towers.

The height of towers is determined by the vertical sag and the clearance required above the ground. If a telephone circuit is below the transmission wires the distance between the telephone and power wires must be added. For instance, if the maximum sag is 12 ft. the telephone 6 ft. below the power wire and the clearance above the ground 20 ft., the tower must evidently support the wires 38 ft. from the ground.

Insulators and Pins.

The insulators and pins must have sufficient mechanical strength to bear the strain transmitted to them from the cable. For example, in the 1000-ft. span just figured on the strain

would be 980 lb. per insulator — ° from the horizontal. A properly-designed porcelain insulator will stand any strain that the pin will bear without bending. A rigid cast-iron or steel pin is therefore essential and can readily be obtained.

The Cross-Arms.

The cross-arm is of course subjected as a beam to the weight and wind strains transferred to it from the cable, but in addition there is a torsional strain due to the breaking of a conductor that can best be borne by a pipe. The length of the cross-arm should be sufficient to space the wires well apart and prevent short circuits either from objects thrown over the line or from the wires coming together. The former is the more important and if a safe distance apart, say six feet, is chosen it will be sufficient to guard against the latter as on short spans with relatively less distance between wires they invariably swing together and never touch each other.

Construction of Towers.

The most economical tower construction is one in which the spread of the legs at the ground is about one quarter to one third the height of the tower. If a less spread is used, the weight of the legs becomes excessive and with a greater spread the cross-bracing must be much increased in size. For a single circuit the common windmill tower construction in which the legs are locked together at the top has the advantage of reducing the strains to a simple compression of the legs on one side and tension on the other, the only function of the cross-bracing being to prevent the legs buckling when in compression.

Where there are two or more circuits the length of the cross-arm is so great as to require two points of support. The tower can then be made with a width at the top approximating that at the bottom and the cross-bracing has to bear its full share of the lateral strains. A truss construction with the fewest number of parts and opportunities for slack motion and rocking of the tower is preferable. Spreading the legs far apart obviates the necessity for expensive concrete foundations, as the strains can be made well within the limits which earth will stand in compression and the weight of earth above the foot of the tower is sufficient to prevent its pulling out of the ground. A heavy galvanizing coating on the tower appears to be an effective protection against rusting and avoids the expense of painting.

This paper has been intentionally confined to the construction of transmission lines and the writer believes it is

more important to-day than the electrical side. To-day the highest pressure employed is 60 000 volts and the longest transmission 150 miles. There is nothing to prevent the use of higher pressures and longer transmissions, provided greater reliability can be obtained by more permanent, substantial, and simpler construction even if greater expense has to be incurred. The writer believes that the use of long spans and metal construction is a most important step in the right direction.

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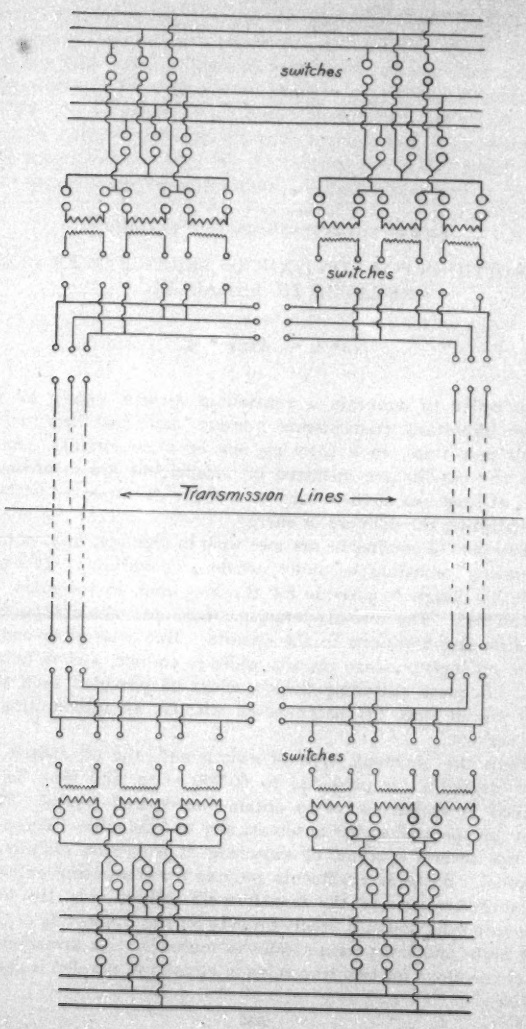
CONDITIONS FOR CONTINUOUS SERVICE OVER LINES OPERATED IN PARALLEL.

BY M. H. GERRY, JR.

In order to maintain a continuous service, nearly all the more important transmission systems have installed two or more pole lines, each carrying one or more circuits. As a rule the circuits are operated in parallel but are so arranged that at least one of them may be entirely disconnected without interrupting the delivery of energy.

Two sets of conditions are met with in practice: first, normal operating conditions; secondly, accidental conditions. It is possible by design to provide for the first, and, in the main, for the second. The normal operating conditions include inspection, repairs, and additions to the circuits. But little work can be done on high-pressure circuits while in service, and it follows that adequate switching devices must be provided such that any circuit may be disconnected without an interruption of the service.

Both the air-break type of switch and the oil switch are now available for pressures to 60 000 volts, and may be installed in various ways to obtain the desired results. They may be operated either automatically or manually. There are in use several systems of switching transmission circuits in parallel. Some arrangements provide for connecting only the low-pressure side of the transformers; others only the high-pressure side, and still others provide for the connecting of both the high- and low-pressure sides in multiple. An arrangement of connections for two transmission circuits in parallel is shown below.


switches
switches
Transmission Lines
switches

This system may be elaborated by adding group-switches on one or both sides of the transformers. If more than two circuits, or more than two banks of transformers be employed, various devices are resorted to for providing the required flexibility. Practice in this last connection has taken the direction of sectionalized bus-bars, with some form of group switching In addition to the switching devices at either end, it is desirable on long lines to instal sectionalizing and paralleling switches so arranged that a section of a transmission circuit may be entirely isolated and the remainder continue in parallel with the other circuits. The switches for this purpose are usually mounted on the poles and are operated manually. It is probable that the practice of sectionalizing long transmission lines will be extended in future and that improved switching apparatus will be employed for this purpose.

In addition to normal operation, the accidental conditions which may arise and affect the continuity of the service should be anticipated and provided for. These conditions, whatever may be their primary cause, usually result in an open circuit, a short circuit, or a grounding of the conductors. Whenever one of these occurs it is essential that the entire circuit, or at least the defective section, be immediately isolated from the other circuits of the system. This may be accomplished either by automatic devices or by the attendants. The automatic methods, on account of the time element involved, are undoubtedly superior, but the apparatus should be of thoroughly reliable construction and should be frequently tested if the best results are to be obtained. The best practice calls for circuit switches controlled automatically by means of time-limit overload relays at the generating end, and similar switches controlled by time-limit reverse-current relays at the receiving end. These devices properly installed will effectually isolate a transmission circuit in case of trouble, but other conditions must also be considered if the service is to be uninterrupted. Whenever a parallel circuit is disconnected it disturbs the entire system and especially affects the electrical pressure. A long transmission circuit represents a considerable capacity, inductance, and resistance, and when this is removed or placed in parallel to other circuits, it becomes necessary to readjust the pressure. This is usually done by the attendants at the generating station but a reliable automatic device would be of value for this purpose if designed to meet all the requirements of transmission service.

A considerable change in pressure at the receiving end of the line may result in an interruption if induction motors or synchronous apparatus be operated by the current. The greater the number of circuits in parallel, the smaller the amount of disturbance produced by removing a single circuit. Many of the better high-pressure transmissions depend, however, upon two lines of one circuit each, and in case of accidental difficulty with one of the circuits, the entire load is carried temporarily on the other line. By a proper design this may be successfully accomplished, and even in the case where one of the circuits is suddenly isolated by automatic devices, the variation of pressure may be kept within such limits that there will be no interference with the service.

The reliability of high-pressure and long-distance transmission has been thoroughly demonstrated, and it has been shown by actual results that a continuous service can be maintained for indefinite periods by the use of multiple lines and proper appliances.

A paper to be presented at the 188th Meeting of the American Institute of Electrical Engineers, Chicago, June 21-22, 1904.

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THE USE OF GROUND-SHIELDS IN TRANSFORMERS.

BY J. S. PECK.

In any transformer there is a possibility that the high-pressure winding may become metallically connected to the low-pressure winding through failure of the insulation between these windings, so that if the low-pressure winding is not connected to ground it may be raised to a high potential above the earth. Under these conditions a person coming in contact with the low-pressure circuit may receive a dangerous shock, while the apparatus connected to this circuit is subjected to undue strains. If, however, the low-pressure winding is connected to ground, the maximum difference of potential which can exist between any part of it and ground is that which is established between the grounded point and that portion of the winding farthest removed, electrically, from the ground.

The ground-shield is a metallic sheet so placed between the high- and low-pressure windings of a transformer that the high pressure cannot break through to the low pressure without first going to ground. The ground-shield should be made preferably of copper, of a thickness of approximately 1/32 in., though it may be of any conducting material, and of practically any thickness desired. A convenient arrangement is to connect the ground-shield to the core of the transformer, which is grounded directly, or through the case. It is obvious that since the ground-shield surrounds the magnetic circuit it must not form a complete turn, and for this reason it is cut through in one place and the joint insulated.

While upon first thought the use of a ground-shield would appear to eliminate entirely the possibility of an abnormal pressure existing between low-pressure winding and ground,

there are, nevertheless, ways in which it may fail in accomplishing its purpose, and there are numerous practical difficulties in its use, particularly in large high-pressure transformers.

Some of the objections to the ground-shield are:

1. It does not prevent the possibility of an abnormally high pressure existing between low-pressure winding and ground, due to a connection between high- and low-pressure leads inside the case, or in the wiring exterior to the transformer.

2. The ground-shield must be of thin material. With transformers of large size where enormous current may flow in case of a short circuit, it is possible that a portion of the shield may be burned away or that the connection between it and the ground connection may be burned off, thus leaving the high- and low-pressure windings connected, but insulated from ground.

3. The introduction of the ground-shield into a transformer increases its cost, or lowers its efficiency, or both; for the same amount of insulation must be placed between the high-pressure winding and the ground-shield as is ordinarily placed between high- and low-pressure windings; and in addition the ground-shield must be insulated from the low-pressure winding.

4. In transformers there is a leakage magnetic field between high- and low-pressure coils. In that portion of the coils outside the iron this leakage field cuts through the ground-shield, producing eddy currents which may greatly increase the transformer losses. This is particularly true on high-pressure transformers where it is necessary for insulation purposes to make a difference in the lengths of the coils. On such transformers it is necessary to use very thin sheet-metal for the shield, and to slit it at the ends into a number of narrow strips, which are insulated from each other, except at one point.

Conclusions.—Since the ground-shield does not afford absolute protection, and as it increases the cost or reduces the efficiency of the transformer, and on account of the mechanical and electrical difficulties involved in its use, it would seem that for large high-pressure transformers the ground-shield is a theoretical, rather than a practical, means of protection.

It is believed that the grounding of the low-pressure winding at the neutral point is a safer, more practical, and cheaper method of protection than is the use of the ground-shield.

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THE PROTECTION OF HIGH-PRESSURE TRANSMISSION LINES FROM STATIC DISCHARGES.

BY H. C. WIRT.

The various devices for the protection of transmission lines from lightning and other static stresses, made by the leading electric companies, are constantly modified, and it is apparent that improvement in this class of apparatus is needed. The best way to develop such devices is to make a careful examination of the transmission lines and of apparatus that may have been damaged by such high-pressure discharges. It is to be hoped that the following comments on various devices now in use will be of interest, and will bring out discussion of their operation.

Ground-Wires.—Overhead ground-wires have been used in several transmission plants. It is evident that if efficient protection can be secured at the power-house and sub-stations, it is superfluous to use such an overhead wire. If a ground-wire be used, it must be large enough not to break and of material that will stand corrosion; a suitable wire will cost almost as much as an additional transmission wire.

A certain power transmission plant, having three power-houses and seven sub-stations, operating 90 miles of overhead transmission lines at 40 000 volts, has protected the greater part of its transmission system by No. 4 galvanized iron wire placed at the top of the poles, half the length being barbed wire, the other half plain wire,—the wire being grounded at every fifth pole. This wire was installed about 14 months ago; before that time many of the poles had been shattered by lightning, but since then no pole has been damaged, but some apparatus has suffered from lightning, the arc jumping from the trans-

former lead above the oil, in all cases. If lightning arresters had been placed at all the stations, and no overhead wire used, there would probably have been less damage to apparatus, but the poles would have been shattered. It is not at present the custom to use lightning arresters on transmission lines, and it is not known whether poles can be protected in any other way than by an overhead ground-wire. It would be of interest to have data upon the frequency of interruption of service of transmission lines on account of poles being damaged by lightning. My opinion at present is that a transmission line can be protected from lightning discharges by suitable apparatus placed in the stations, and that it is not necessary to use ground-wires; but an exception will probably have to be made in cases where poles are shattered with great frequency.

Another installation, operating at 25 000 volts, uses lightning arresters at stations and sub-stations, with reactive coils, constructed to break down at 50 per cent. above the working pressure, and with a resistance in the ground connection. The arresters have a series of gaps, and are equipped with the "multiplex connection," giving a minimum breakdown distance between line and line. Prior to the installation of this equipment, there was frequent loss of apparatus at the stations, but since, no apparatus has failed on account of lightning, although there have been many severe storms. The management of this plant had begun to equip the transmission lines with a ground-wire, but has decided not to proceed with this plan.

We have in these two cases entirely opposite methods of protecting lines. In one case, the management is so well satisfied with ground-wires that lightning arresters will not be used; in the second case, the management is so well satisfied with lightning arresters that ground-wires will not be used. These two plants are in country very similar in its physical characteristics, and are only a few hundred miles apart.

Experience with apparatus damaged by lightning proves that it is as important to provide an easy path for the lightning discharge from line to line as from line to ground. Up to the present, the principal idea in designing a lightning arrester has been to provide a good path to ground; they have frequently required twice as great a pressure to break down the gap space from line to line as from line to ground. Recently a new type has been suggested called the "multiplex connection," in which a shorter path is provided from line to line, requiring practically

the same breakdown pressure as from line to ground. It is believed that this type will afford additional safety. The photograph herewith shows a particular case in which lightning passing from line to line, jumped across from one terminal to the other of a porcelain primary connection board; to jump this space required 42 000 volts.

Reactive Coils.—Much difference of opinion has existed among engineers on the value of reactive coils, in connection with lightning arresters. Some recent tests made with the best types of lightning arresters show that the arresters did not protect the apparatus until reactive coils were used; it seems now that there can be no question that reactive coils are effective, and therefore they should always be used. Although much has been written upon lightning arresters. there is little available information upon the relative pressure suitable for the spark-gap; it is difficult to determine just how near to the pressure of the generator a spark-gap can be adjusted without danger of flashing over. When apparatus has burned out, it is possible either to increase the insulation resistance or to decrease the spark-gap distance. Many arresters are now supplied, adjusted for a breakdown pressure only 50% greater than the generator pressure; it can be determined only by experience whether it is feasible to set arresters nearer the generator pressure than this; generators are in many cases insulated to stand only 50% increase above the working pressure, and in this case there is no difference between the breakdown pressure of the insulation and the spark-gap; but the insulation of the machine stands a one-minute test and the static stresses exist only momentarily, which is undoubtedly the reason that apparatus has not burned out more frequently. Present experience indicates that apparatus, to be safe, should stand an insulation test of 100% greater than rated pressure for one minute; such apparatus may have to be insulated for higher pressure than the present INSTITUTE standard, as it is extremely difficult to protect apparatus unless it will stand the double-pressure test.

Experiments have shown that very high pressures exist momentarily between the outside turns of the coils of a transformer at the moments when it is switched into or out of circuit. Transformers insulated for only 1000 volts per turn will withstand these very high pressures momentarily; as the best modern construction of transformers provides for re-

enforcing the insulation in the outside turns, thus providing a larger factor of safety, it is a question where the additional protection against breakdown of the outside turns should be provided; a rise of temperature on switching transformers has been noticed in some installations, which is attributed to capacity and reactance, producing resonance, and it has become the practice to provide special means to obviate any rise of pressure due to these causes; such apparatus is known as a "static-arrester." It is necessary only to provide a circuit having a moderate current capacity in order to relieve the line of high pressure, due to these causes.

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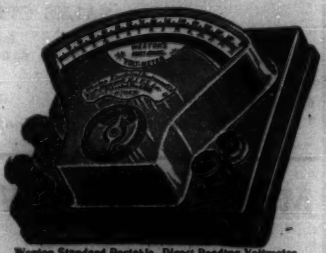

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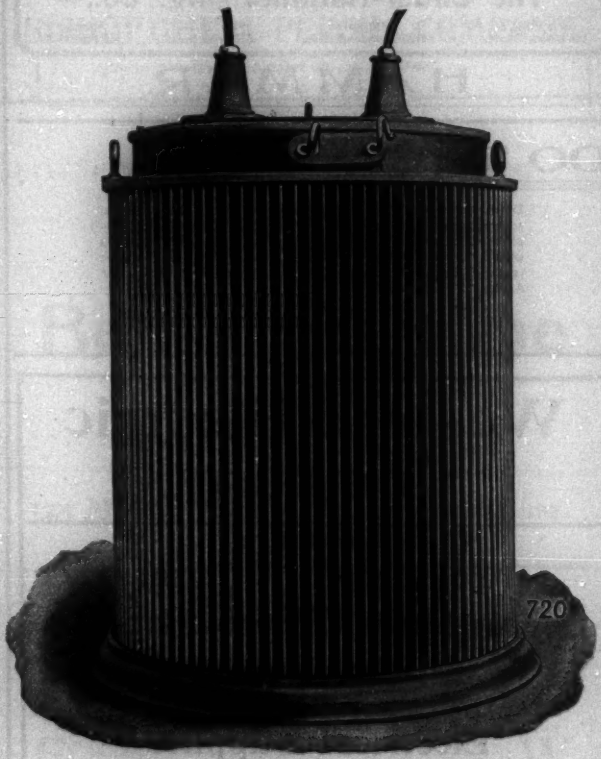

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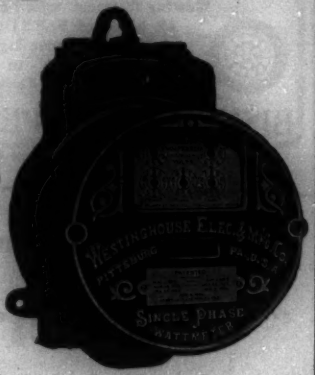

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